PROCEEDINGS OF THE I·R·E

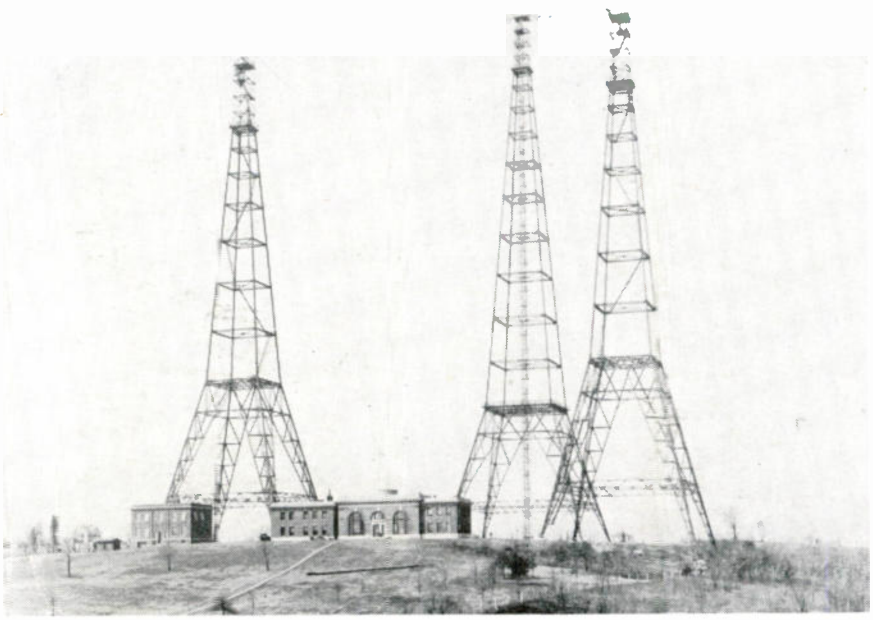
AND

WAVES AND ELECTRONS

1947

I.R.E. NATIONAL CONVENTION
IN NEW YORK

March 3, 4, 5, 6 and 7



Official U. S. Navy Photograph

LANDMARK OF PIONEER RADIO DEVELOPMENTS
The Towers of Station NAA at Arlington, Virginia.

December, 1946

Volume 34 Number 12

PROCEEDINGS OF THE I.R.E.

Waves and Electrons Section

The Institute of Radio Engineers

FOR HIPERM ALLOY TRANSFORMERS

The UTC Hiperm alloy audio transformers are specifically designed for portable and compact service. While light in weight and small in dimensions, neither dependability nor fidelity has been sacrificed. The frequency characteristic of the Hiperm alloy audio units is uniform from 30 to 20,000 cycles. These units are similar in general design and characteristics to the famous Linear Standard audio Series.

UTC Hiperm Alloy Transformers Feature

True Hum Balancing Coil Structure... maximum neutrolization of stray fields.

Balanced Variable Impedance Line . . . permits highest fidelity on every tap of a universal unit . . . no line reflections or transverse couplings.

Reversible Mounting . . . permits above chassis or sub-chassis wiring.

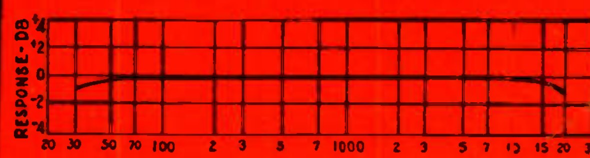
Alloy Shields . . . maximum shielding from induction pick-up.

Multiple Coil, Semi-Toroidal Coil Structure minimum distributed capacity and leakage reactance.

High Fidelity . . . UTC Hiperm Alloy Transformers have a guaranteed uniform response of ±1.5DB from 20-20,000 cycles.

FOR IMMEDIATE DELIVERY

From Your Distributor



Typical Curve for HA Series

Type No.	Application	Primary Impedance	Secondary Impedance	± 1 db from	Max. Level	Max Unbal. DC in primary	List Price
HA-100	Low impedance mike, pickup, or multiple line to grid.	50, 125, 200, 250, 333, 500 ohms	60,000 ohms in two sections	30–20,000	+22 DB	5 MA	18.60
HA-100X	Same as above but with tri-alloy internal shield to effect very low hum pickup.						23.95
HA-101	Low impedance mike, pickup, or multiple line to push-pull grids.	50, 125, 200, 250, 333, 500 ohms	120,000 ohms overall, in two sections	30–20,000	+22 DB	5 MA	21.25
HA-101X	Same as above but with tri-alloy internal shield to effect very low hum pickup.						26.60
HA-108	Mixing, low impedance mike, pickup or multiple line.	50, 125, 200, 250, 333, 500 ohms	50, 125, 200, 250, 333, 500 ohms	30–20,000	+22 DB	5 MA	18.60
HA-106	Single plate to push-pull grids	8,000 to 15,000 ohms	135,000 ohms 1.5:1 ratio, each side	30–20,000	+22 DB	0	15.95
HA-113	Single plate to multiple line.	8,000 to 15,000 ohms	50, 125, 200, 250, 333, 500 ohms	30–20,000	+22 DB	1 MA	17.95
HA-134	Push-pull 89's or 2A3's to line.	5,000 to 10,000 ohms	50, 125, 200, 250, 300, 500 ohms	30–20,000	+32 DB	5 MA	19.95
HA-135	Push-pull 2A3's to voice coil.	3,000 to 5,000 ohms	30, 20, 15, 10, 7.5, 5, 2.5, 1.2	30–20,000	+32 DB	5 MA	18.60

The above listing includes only a few of the many Hiperm Alloy Transformers available . . . write for catalog.

United Transformer Corp.

150 VARICK STREET NEW YORK 13, N. Y.

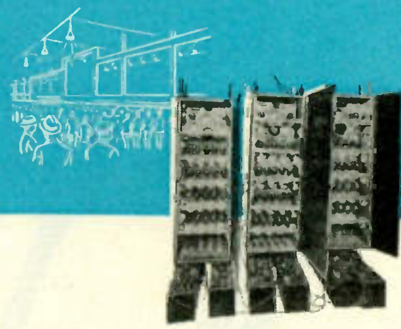
EXPORT DIVISION: 13 EAST 40th STREET, NEW YORK 16, N. Y., CABLES: "ARLAB"

Proceedings of the I.R.E. and Waves and Electrons, December, 1946, Vol. 34, No. 12. Published monthly in two sections by The Institute of Radio Engineers, Inc., at 1 East 79 Street, New York 21, N.Y. Price $1.25 per copy. Subscriptions: United States and Canada, $12.00 a year; foreign countries $13.00 a year. Entered as second class matter, October 26, 1927, at the post office at Menasha, Wisconsin, under the act of March 3, 1879. Acceptance for mailing at a special rate of postage is provided for in the act of February 28, 1925, embodied in Paragraph 4, Section 412, P. L. and R., authorized October 26, 1927.

Table of contents will be found following page 32C

Why this team stands

1914. World's first vacuum tube repeater amplifier; designed by Bell Telephone scientists and made by Western Electric for transcontinental telephony, was the start of modern electronic communications.



1919. These Western Electric amplifiers powered the mightiest sound system of its day, used at New York's "Victory Way" Celebration after World War I. There were 113 loudspeakers in the system.

WHEN Bell Telephone scientists designed and Western Electric manufactured the first vacuum tube repeater amplifier back in 1914, they opened a vast new frontier of communications and sound distribution. Up to that time, telephone communications—both by wire and radio—could cover only limited distances and produce relatively low volumes.

For more than 30 years, this team has produced ever better amplifiers for almost every use—long distance wire and radio telephony, radio broadcasting, sound distribution systems, mobile radio, sound motion pictures, disc recording, acoustic instruments and radar.

Equipped with unexcelled tools of research, experience, skill and manufacturing facilities, the Bell Laboratories-Western Electric team will continue to design and build amplifiers outstanding in quality, efficiency and dependable performance.

— QUALITY COUNTS —

BELL TELEPHONE LABORATORIES

World's largest organization devoted exclusively to research and development in all phases of electrical communications.

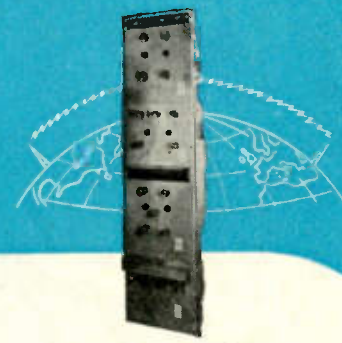
Western Electric

Manufacturing unit of the Bell System and the nation's largest producer of communications equipment.

for *Quality* in Amplifiers

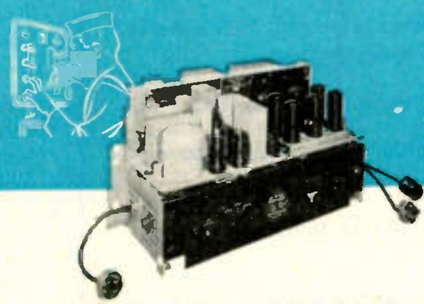
1922. The Western Electric 8A was the first commercial broadcasting amplifier. Today, 24 years later, some of these 8A's are still in use. This long life speaks volumes for the quality built into them.

1928. This ac operated amplifier, one of the first made, reduced maintenance costs and did away with cumbersome batteries and charging equipment. It was used to record some of the earliest sound motion pictures.



1934. Western Electric was an early leader in making compression type amplifiers to enable higher speech intensity between noise level and overload point. This equipment was used in overseas radiotelephony.

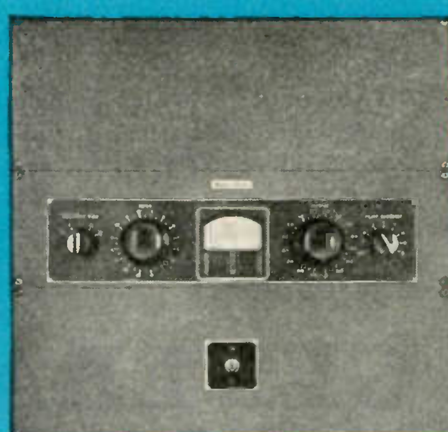
1946. The brand new 124H and J amplifiers for wired music and public address systems are small and light weight, yet deliver 20 watts. They are setting new standards of quality for music reproduction.



1942. This compact and powerful unit for battle announce systems is typical of Western Electric amplifiers designed during the war. It operated dependably when mounted a few feet from the largest guns.

1938. Negative feedback is another of Bell Laboratories' many contributions to amplifier design—now in general use. This amplifier for disc recording was able to supply as much as 50 db of feedback

1946. The 1126C is the latest design of Western Electric's popular level governing amplifiers. In operation it acts as a program-operated gain control to prevent overmodulation in AM or FM broadcasting. It immediately reduces gain when an instantaneous peak exceeds a predetermined level, slowly restores it when the peak is passed.



Distributed by
GraybaR
OFFICES IN 95 PRINCIPAL CITIES

FORCED-AIR COOLED

NEW V-H-F POWER TRIODE FOR 10-KW FM

TYPE GL-5518

- **High power output—see ratings!—yet forced-air cooled for convenience of installation.**
- **Frequency up to 110 mc at max plate input.**
- **Ultra-modern in design and electrical characteristics.**
- **G-E Ring-Seal construction gives large terminal-contact areas.**
- **COMPACT and sturdy. Built to "take it" in hard station service.**

RATINGS

Filament voltage	6.3 v
Filament current	250 amp
Grid-plate transconductance	12,000 mhos
Interelectrode capacitances:	
Grid-filament	28.5 mmfd
Grid-plate	20 mmfd
Plate-filament	0.55 mmfd
Frequency at max ratings	110 mc
Type of cooling	forced air
Plate ratings per tube, Class C power amplifier, grounded-grid circuit (key-down conditions without modulation):	
Max voltage	7,500 v
Max current	2 amp
Max input	12 kw
Max dissipation	4 kw
USEFUL POWER OUTPUT, typical operation (at 6,000 v and 1.3 amp)	6.4 kw

BROADCAST stations that prefer forced-air cooling, and builders of transmitters for this type service, both will welcome General Electric's Type GL-5518 triode—a NEW v-h-f tube with plenty of power, modern in every way, able to meet the exacting demands of FM with plus-marks for its performance.

A pair of GL-5518's, operating conservatively in a grounded-grid amplifier, will put out more than 12½ kw of power. *Usually the GL-5518 needs no neutralization in grounded-grid circuits;* but when required, a small amount of fixed neutralization suffices over a wide frequency band.

To these features should be added:

1. Extremely low lead inductance.
2. Minimum r-f losses due to silver-plating all external metal parts.
3. Topnotch electrical efficiency from generous ring-seal terminal-contact areas.

Let G-E tube engineers work with you to apply the GL-5518 to new equipment for the big FM broadcast market that favors air-cooling. Phone your nearby G-E office, or write *Electronics Department, General Electric Company, Schenectady 5, New York.*

GENERAL ELECTRIC

161-E19-8850

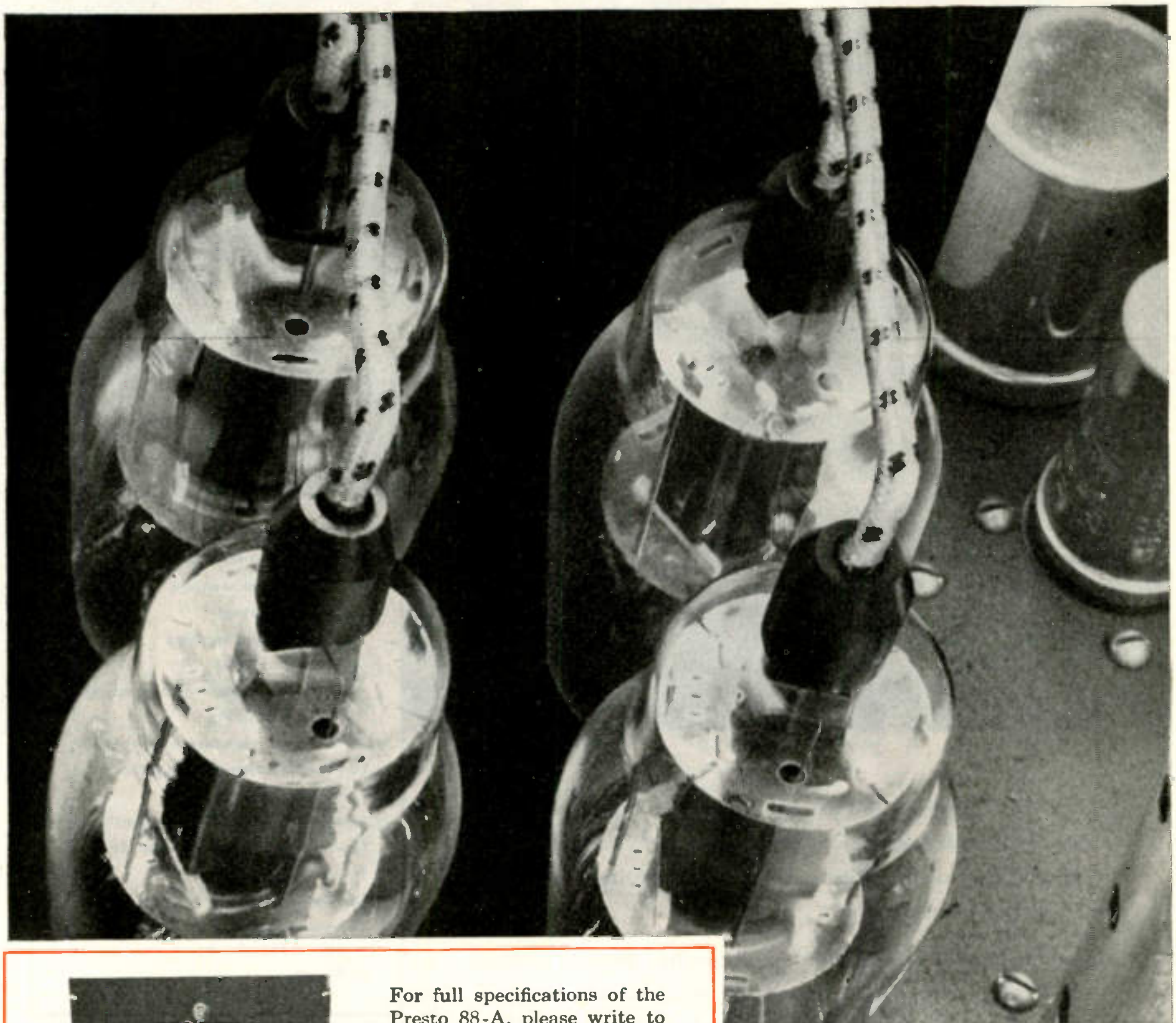
FIRST AND GREATEST NAME IN ELECTRONICS

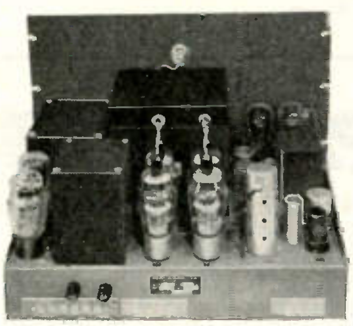
Four 807's Push-Pull Parallel

▶ The Presto 88-A is a 50-watt amplifier designed specifically to drive the modern wide range magnetic recording head, such as the Presto 1-D. Its very ample output stage—four 807's in push-pull parallel—provides adequate power at peak levels with a minimum of distortion. A selector switch provides a choice of:

1. Flat response 20 to 17,000 cycles per second, $\pm$ 1 db.
2. The NAB recording characteristic.
3. Rising characteristic for vertical recordings.

▶ The Presto 88-A is ideal for the most exacting recording requirements.





For full specifications of the Presto 88-A, please write to the Presto Recording Corporation, 242 West 55th Street, New York 19, N. Y. To insure future delivery within a reasonable time, we suggest that you place your order on our priority list since orders are considerably in advance of production.

PRESTO

RECORDING CORPORATION

242 WEST 55TH STREET, NEW YORK 19, N. Y.

Walter P. Downs, Ltd., in Canada

WORLD'S LARGEST MANUFACTURER OF INSTANTANEOUS SOUND RECORDING EQUIPMENT & DISCS

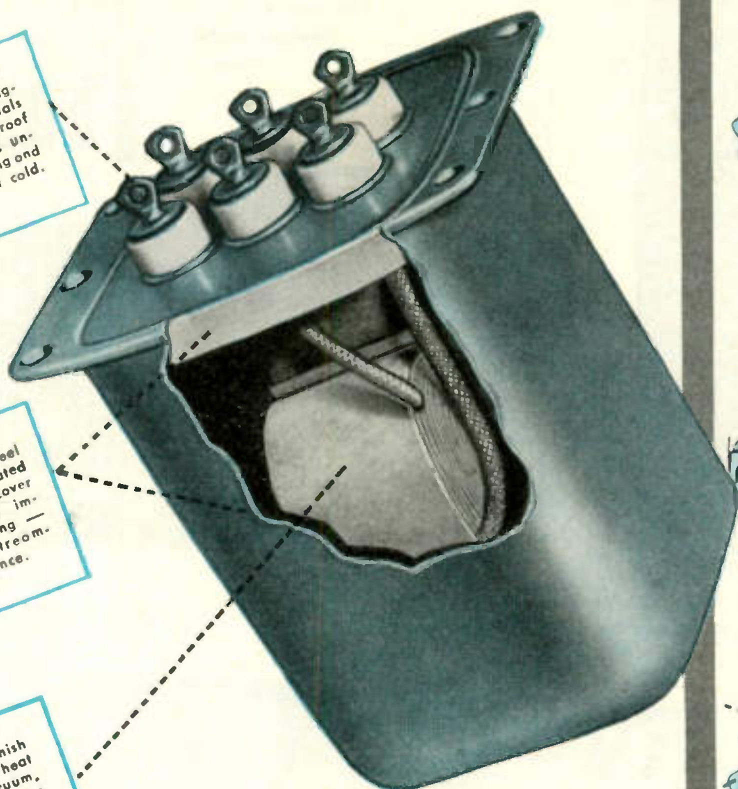
For an Extra Margin of

DEPENDABILITY

UNDER ALL OPERATING CONDITIONS

CASE TYPE

CHICAGO TRANSFORMERS
Sealed in Steel



Exclusive C. T. bushing-gasket seal at terminals is permanently proof against moisture, is unimpaired by soldering and by climatic heat or cold.

Seamless drawn steel case and C. T.-innovated "Deep-Seal" base cover provide a strong, impenetrable housing — rust-proofed, streamlined in appearance.

Coil is wax and varnish impregnated under heat and alternating vacuum, pressure, to remove moisture, prevent its reentrance during assembly of unit.

Sealed AGAINST ATMOSPHERIC MOISTURE AND INDUSTRIAL FUMES

THUS *Sealed* AGAINST CORROSION OF COPPER COIL WINDINGS

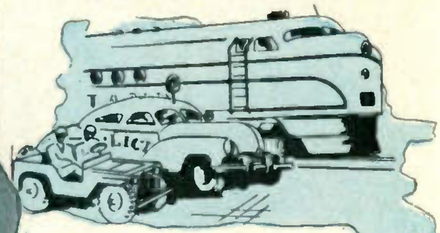
STAY *Sealed* IN EXTREMES OF HEAT AND COLD!

FITTED TO THE APPLICATIONS WHERE COMPONENT DEPENDABILITY IS ESSENTIAL TO

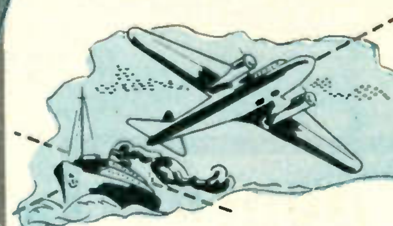
Avoid

COSTLY MAINTENANCE
LOSS OF LIFE
DISRUPTION OF A VITAL SERVICE

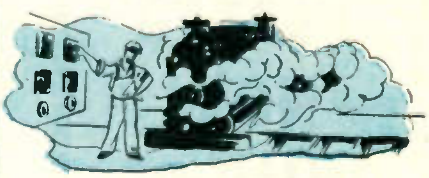
RADIO AND TELEVISION BROADCASTING
FIXED, MOBILE, & SATELLITE EQUIPMENT



MILITARY, POLICE, AND RAILROAD COMMUNICATIONS



ELECTRONIC NAVIGATIONAL AIDS FOR SHIPS AND AIRLINES



INDUSTRIAL CONTROLS

★ In these and many other transformer applications, economy, as well as efficiency, is best served by Chicago Transformer's *Sealed in Steel* construction.

Let its assurance of long-lasting transformer reliability help make your electronic product free of component replacements and expensive servicing regardless of adverse operating conditions.

CHICAGO TRANSFORMER

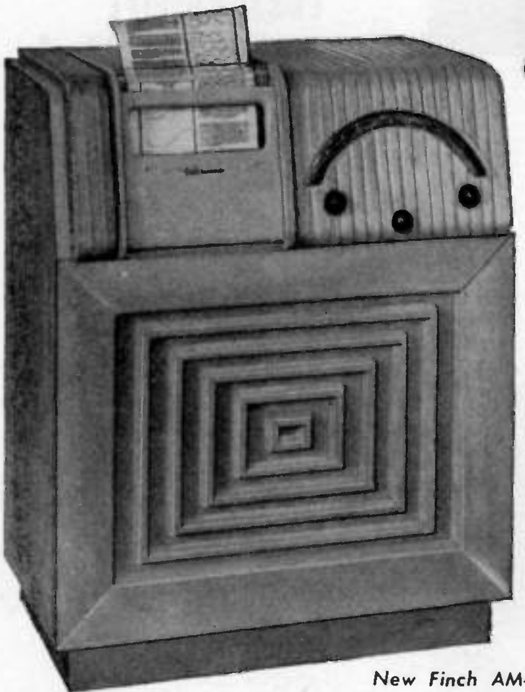
DIVISION OF ESSEX WIRE CORPORATION

3501 ADDISON STREET • CHICAGO 18, ILLINOIS

NEWEST

FACSIMILE Broadcasting Equipment

finch



New Finch AM-FM Radio for receiving both sound and facsimile. Console model

New Finch AM-FM Radio for receiving both sound and facsimile. Table model

ORDERS PLACED NOW WILL BE GIVEN PRIORITY

Complete Finch Facsimile Broadcast Transmitter and Monitor Control Desk

FINCH TELECOMMUNICATIONS, INC. • Address all inquiries to Sales Office 10 EAST 40th STREET • NEW YORK 16, N. Y.

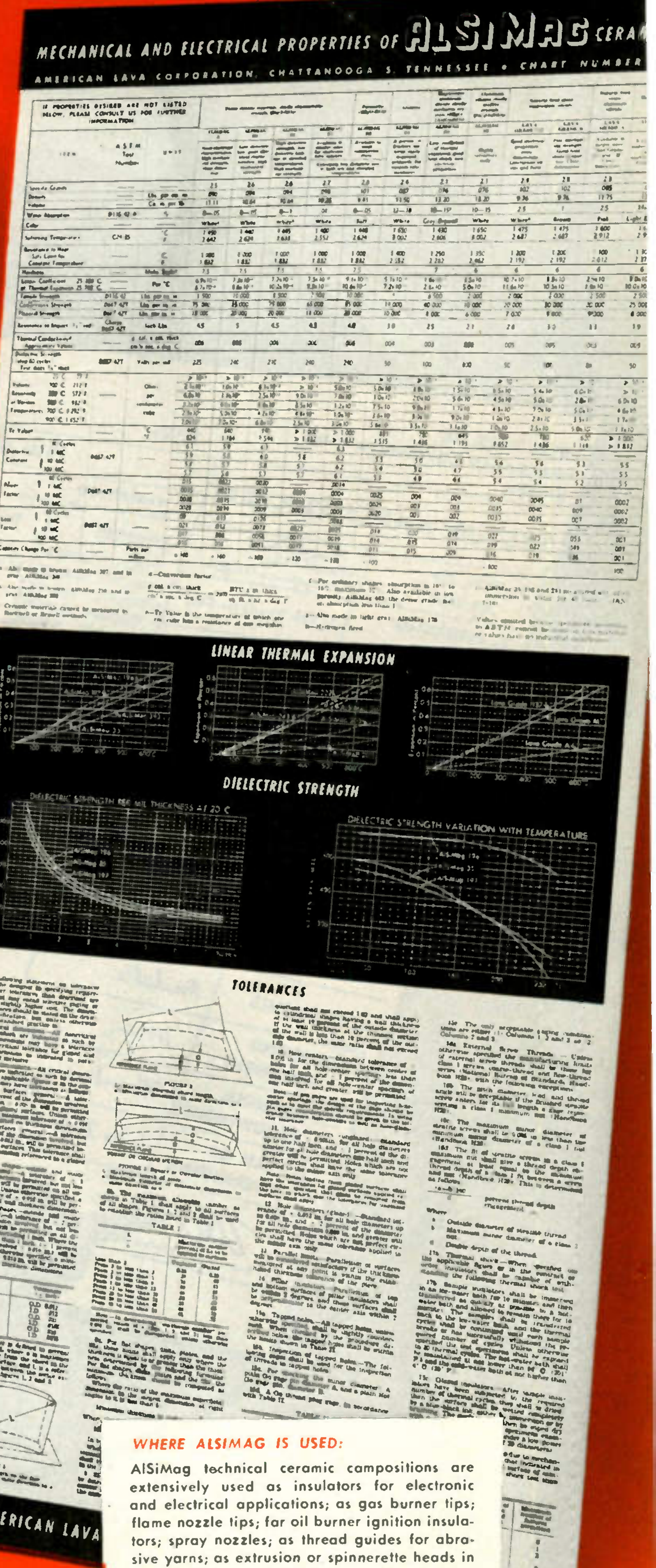
Makers of Facsimile Broadcast Transmitting Equipment, Facsimile Home Recorders, Facsimile Duplicating Machines, and Finch Rocket Antenna for FM stations.

New Property Chart of ALSIMAG

TRADE MARK REGISTERED U.S. PATENT OFFICE

technical ceramic compositions

SENT FREE ON REQUEST



WHAT ALSIMAG IS:

AlSiMag is the trade name of a large family of technical ceramic compositions. These compositions have different physical, electrical, mechanical and chemical characteristics. AlSiMag parts are custom made to specifications.

WHAT THE CHART TELLS:

The properties of the more frequently used AlSiMag compositions have been accurately determined and reproduced in chart form for quick reference.

ALSIMAG COMPOSITIONS NOT ON CHART:

Many special AlSiMag compositions have been developed to meet specific conditions. These are too numerous to chart. If chart indicates general characteristics of value, modifications to suit your special application may be available.

WHO NEEDS THE CHART:

Any designing engineer, production technician or purchasing agent will find chart helpful in his search for materials for unusual applications.

HOW TO GET THE CHART:

The AlSiMag Property Chart is sent free on request. Request as many copies as you need to cover your organization. Write to:

AMERICAN LAVA CORPORATION

44TH YEAR OF CERAMIC LEADERSHIP

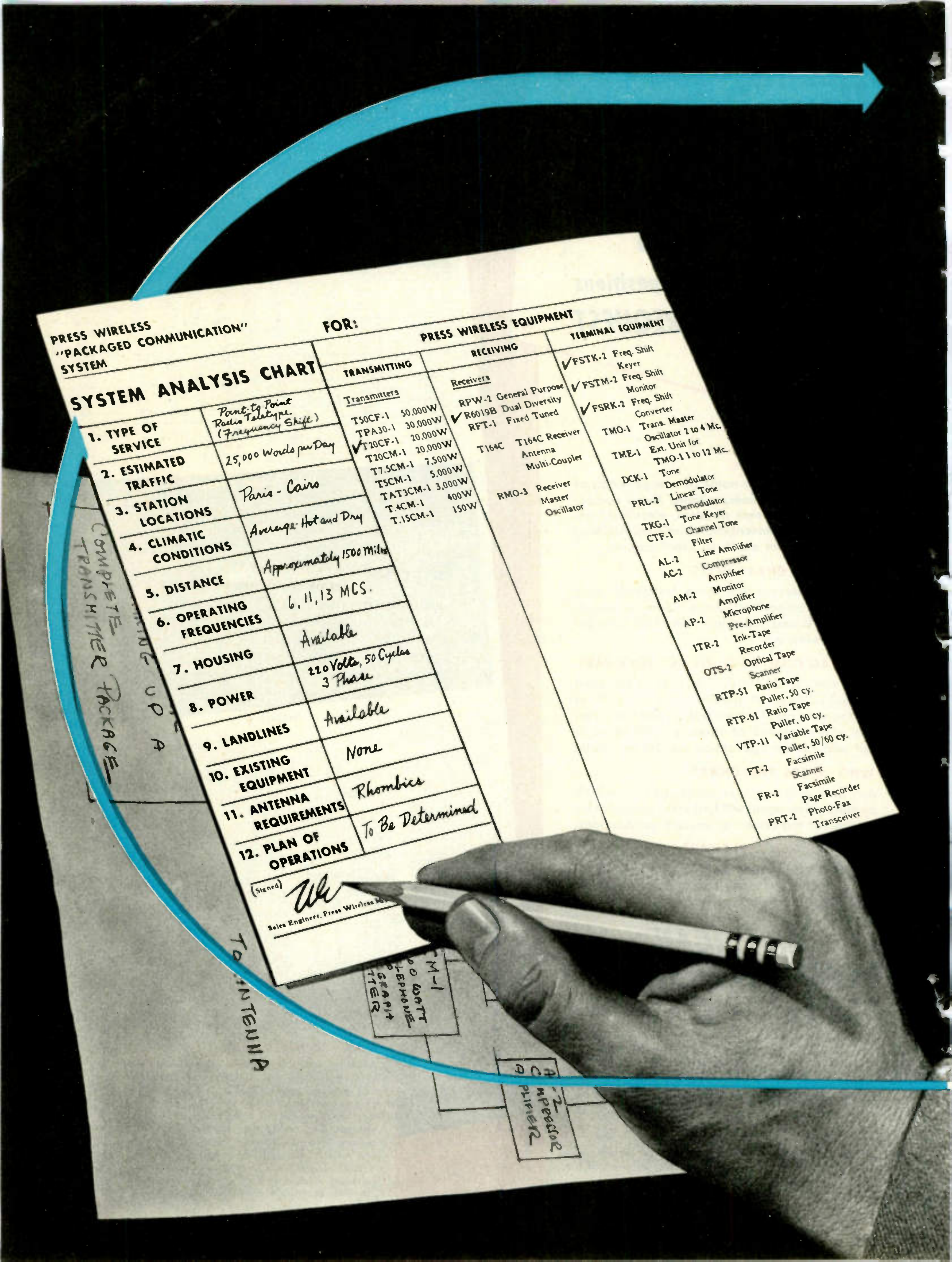
CHATTANOOGA 5, TENNESSEE

ENGINEERING SERVICE OFFICES: ST. LOUIS, Mo., 1123 Washington Ave., Tel: Garfield 4959 • NEWARK, N. J., 671 Broad St., Tel: Mitchell 2-8159 • CAMBRIDGE, Mass., 38-B Brattle St., Tel: Kirkland 4498 • CHICAGO, 9 S. Clinton St., Tel: Central 1721 SAN FRANCISCO, 163 Second Street, Tel: Douglas 2464 LOS ANGELES, 324 N. San Pedro St., Tel: Mutual 9076

Printed one side only, folded to file size. For use under desk glass or as a wall chart or in standard file.

WHERE ALSIMAG IS USED:

AlSiMag technical ceramic compositions are extensively used as insulators for electronic and electrical applications; as gas burner tips; flame nozzle tips; for oil burner ignition insulators; spray nozzles; as thread guides for abrasive yarns; as extrusion or spinnerette heads in certain fibre or chemical processes; as cores and inserts for precision castings; in work holders for electronic heating devices—in short wherever electricity, heat, chemical or certain abrasive or friction conditions must be controlled.


PRESS WIRELESS
"PACKAGED COMMUNICATION"
SYSTEM
SYSTEM ANALYSIS CHART
FOR:
PRESS WIRELESS EQUIPMENT
TRANSMITTING
RECEIVING
TERMINAL EQUIPMENT
1. TYPE OF SERVICE
Point-to Point Radio Teletype (Frequency Shift)
2. ESTIMATED TRAFFIC
25,000 Words per Day
3. STATION LOCATIONS
Paris - Cairo
4. CLIMATIC CONDITIONS
Average - Hot and Dry
5. DISTANCE
Approximately 1500 Miles
6. OPERATING FREQUENCIES
6, 11, 13 MCS.
7. HOUSING
Available
8. POWER
220 Volts, 50 Cycles 3 Phase
9. LANDLINES
Available
10. EXISTING EQUIPMENT
None
11. ANTENNA REQUIREMENTS
Rhombics
12. PLAN OF OPERATIONS
To Be Determined
(Signed)
Sales Engineer, Press Wireless
Transmitters
T50CF-1 50,000W
TPA30-1 30,000W
✓T20CF-1 20,000W
T20CM-1 20,000W
T7.5CM-1 7,500W
T5CM-1 5,000W
TAT3CM-1 3,000W
T.4CM-1 400W
T.15CM-1 150W
Receivers
RPW-2 General Purpose
✓R6019B Dual Diversity
RFT-1 Fixed Tuned
T164C T164C Receiver Antenna Multi-Coupler
RMO-3 Receiver Master Oscillator
✓FSTK-2 Freq. Shift Keyer
✓FSTM-2 Freq. Shift Monitor
✓FSRK-2 Freq. Shift Converter
TMO-1 Trans. Master Oscillator 2 to 4 Mc.
TME-1 Ext. Unit for TMO-1 1 to 12 Mc.
DCK-1 Tone Demodulator
PRL-2 Linear Tone Demodulator
TKG-1 Tone Keyer
CTF-1 Channel Tone Filter
AL-2 Line Amplifier
AC-2 Compressor Amplifier
AM-2 Monitor Amplifier
AP-2 Microphone Pre-Amplifier
ITR-2 Ink-Tape Recorder
OTS-2 Optical Tape Scanner
RTP-51 Ratio Tape Puller, 50 cy.
RTP-61 Ratio Tape Puller, 60 cy.
VTP-11 Variable Tape Puller, 50/60 cy.
FT-2 Facsimile Scanner
FR-2 Facsimile Page Recorder
PRT-2 Photo-Fax Transceiver
COMPLETE TRANSMITTER PACKAGE
TO ANTENNA

Here's how we "pack" the PW package

EVERY potential radio communication system presents problems peculiar to its individual requirements. Each problem must be approached with the proper attitude and answered methodically in orderly sequence. The PW System Analysis Chart serves as a valuable aid to both the client and the sales engineer . . . it enables both to work out the problem efficiently.

Peek over the shoulder of a PW sales engineer as he makes his first contact with a prospective client. Notice that only the basic units have been selected . . . those obviously essential, from the list of available PW equipment.

These basic units are then assembled together with whatever associated equipment is required to complete the proposed communication system. This system is engineered, from start to finish, by Press Wireless who for the past seventeen years has designed, built and maintained a globe-circling network of communication systems . . . transmitting better than 80 percent of the world's press traffic.

PW builds its own equipment. It has been pretested on our own world-wide communication circuits. There is no guess work when you submit your communication problem to PW. You obtain . . . from one source, under one contract . . . all the factors of analysis, design, engineering, manufacturing and erection that go to make up a successful communication system.

Why not take advantage of PW experience *today* and let us assist you with your communication problem. PW "packaged" communication equipment is your logical answer.

Please address inquiries, Dept. 708A, Press Wireless Manufacturing Corporation, Executive Offices, 1475 Broadway, New York 18, N. Y., U. S. A.

UNITS IN THE PW "PACKAGE"

RADIO-TELEGRAPH
AND TELEPHONE TRANSMITTERS
FREQUENCY SHIFT
RADIO-PHOTO
COMMUNICATION RECEIVERS
PLUS
ASSOCIATED TERMINAL
EQUIPMENT

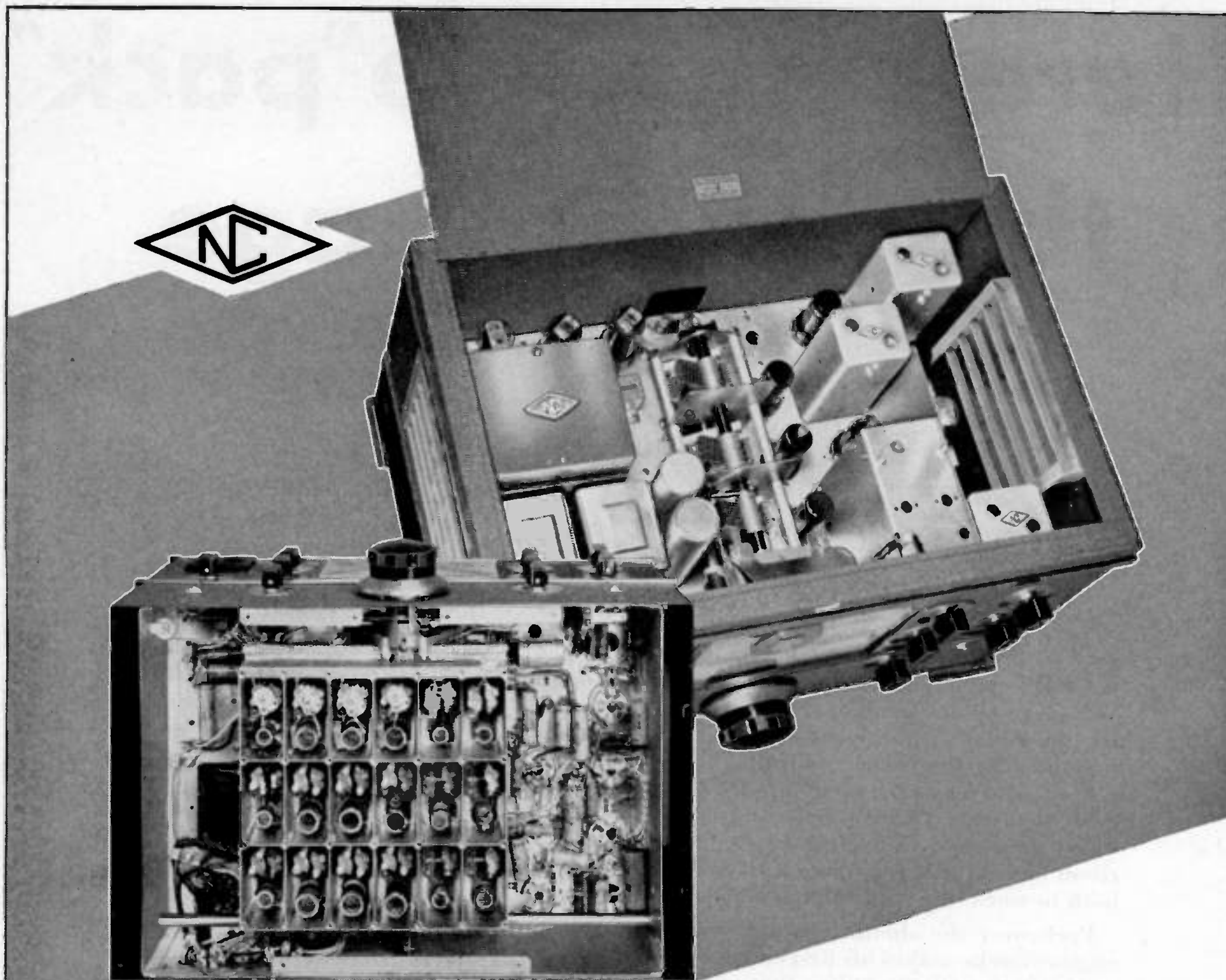
Your installation is engineered from any combination of the above standardized PW units

PRESS WIRELESS INC. PREWI

PW

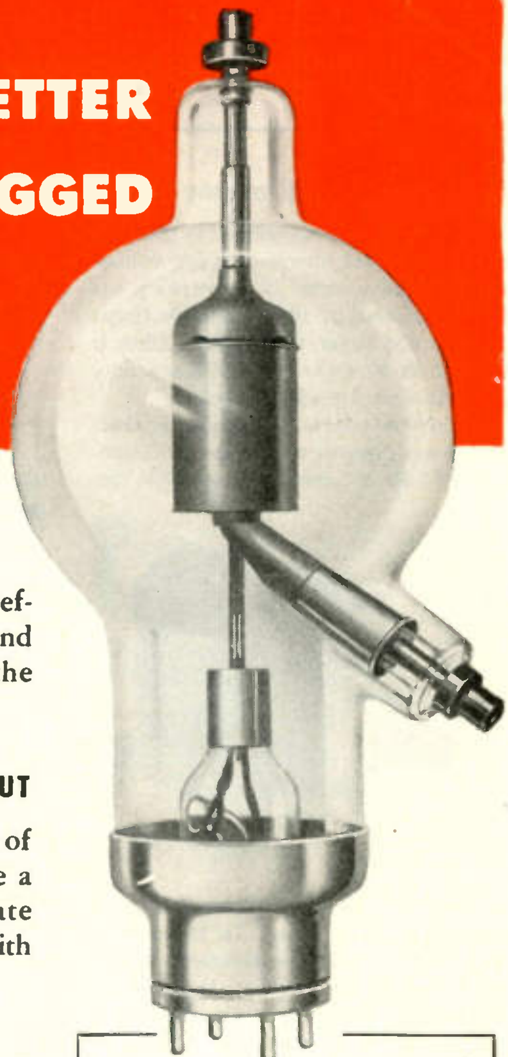
PRESS WIRELESS

First in "Packaged" Communications Equipment



IT'S TOUGH TO FIND A BETTER TRIODE THAN THE BIG, RUGGED

EIMAC 750TL



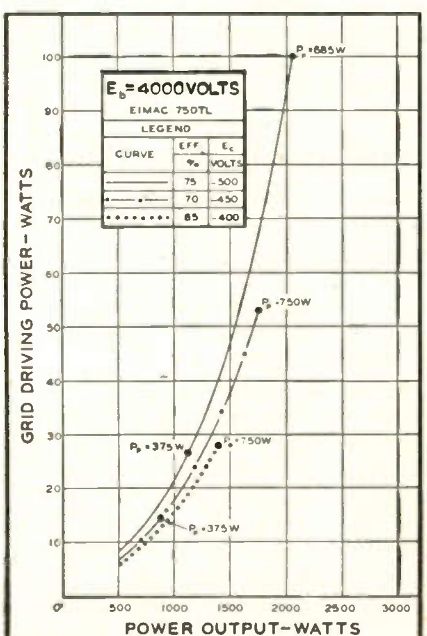
VERSATILE MEDIUM-MU TRIODE

The Eimac 750TL is a medium-mu triode designed for high efficiency operation whether used as a modulator, oscillator or amplifier. This is an unusually versatile tube capable of many kilowatts of output.

Successful high frequency operation of this triode is assured by unusually low interelectrode capacitances, heavy leads, and a big tough cathode.

The chart below shows power-gain characteristics of the 750TL.

As a Class-C amplifier, the Eimac 750TL will provide plate power output of 1750 watts with 4000 volts on the plate and only 53 watts driving power.



At frequencies below 40 mc, or as a Class-B modulator, the 750TL operates at high plate efficiencies, thus permitting r-f and a-f outputs of many times the plate dissipation rating.

3½ KILOWATT AUDIO OUTPUT

As Class-B modulators, a pair of Eimac 750TL's will produce a typical maximum-signal plate power output of 3500 watts, with only 30 watts grid drive.

THESE ARE RUGGED TUBES

These big, powerful 750TL's are built for long, trouble-free service for a wide variety of uses. Many Eimac 750TL's installed months and years ago are still going quietly and efficiently about their business. Why not ask Eimac today for a price and data sheet giving full details of this versatile triode. Naturally, there is no obligation. Eitel-McCullough, Inc., 1298J San Mateo Ave., San Bruno, Calif. Export Agents: Frazar and Hansen, 301 Clay St., San Francisco 11, Calif., U. S. A.

GENERAL CHARACTERISTICS

Eimac 750TL

Filament: Thoriated tungsten	
Voltage	7.5 volts
Current	21.0 amperes
Amplification Factor (Average)	15
Direct Interelectrode Capacitances (Average)	
Grid-Plate	5.8 uufd
Grid-Filament	8.5 uufd
Plate-Filament	1.2 uufd
Transconductance (I_B=1.0 amp., E_B=5000, E_C=—100)	3500 umhos
Frequency for Maximum Ratings	40 Mc
Base	Special 4 Pin No. 5003B
Basing	RMA type 48D
Maximum Overall Dimensions:	
Length	17.0 inches
Diameter	7.125 inches
Net Weight	2.75 pounds
Shipping Weight (Average)	8.0 pounds

Follow the Leaders to

Eimac REG. U. S. PAT. OFF. **TUBES**

THE COUNTERSIGN OF DEPENDABILITY IN ANY ELECTRONIC EQUIPMENT

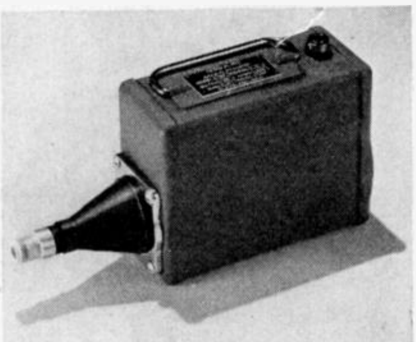
NEWS and NEW PRODUCTS

December, 1946

Coaxial Resistor

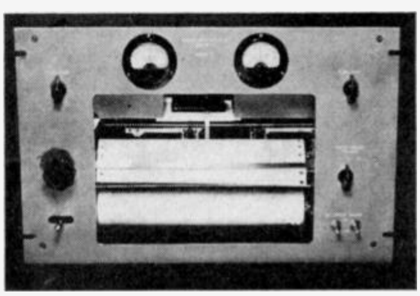
A coaxial resistor designed to dissipate all r-f power fed into it with low voltage standing wave ratio characteristics has been announced by Bird Electronic Corp., 1800 East 38 Street, Cleveland 14, Ohio. It is rated at 50 watts for continuous duty and is immersed in a liquid coolant.

It may be used as an impedance standard, a non-reactive termination to terminate r-f lines, a dummy antenna while tuning up transmitters, and determination of transmission line losses. In conjunction with the slotted-line measurement of voltage standing wave ratios, it eliminates the usual necessity of stub tuners and matching transformers. Further data may be obtained from the manufacturer.



Dual Graphic Recorder

For recording simultaneously two records of the same or different phenomena, Sound Apparatus Company, 233 Broadway, New York 7, N. Y., has developed a graphic recorder known as the Twin-Recorder. Two synchronous motors are employed, one for the writing pens, and the other for driving the recorder at the two chart speeds.

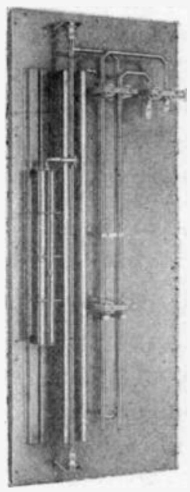


This device conveniently records upon a single record such combinations of measurements as current and voltage, average and r.m.s. values, linear and logarithmic values, and duplicate records at the same time.

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

Iso-Coupler for FM Antennas

The many broadcasters now adding FM facilities may effect something more than a minor economy, (that is, the price of another tower), if they are able to erect their FM antennas atop an existing AM radiator. This does, however, introduce the problem of feeding the FM power without short-circuiting the AM radiator at its frequency or causing cross-talk at the FM frequency.



Coupling equipment which properly isolates the two systems and feeds the FM antenna across the base insulation of the AM tower has been developed and made commercially available by the E. F. Johnson Co., Waseca, Minnesota. This new unit, the ISO-COUPLER, rated up to and including 50 KW AM and 10 KW FM, will match 50-ohm lines from the FM transmitter and does not disturb AM tower impedance.

Gas Free Metals

The multiple advantages of high purity and freedom from gaseous inclusions can now be realized by utilization of high-vacuum techniques in many metal and alloy fields. A partial list of metals so treated by the Vacuum Metals Division of National Research Corp., 100 Brookline Ave., Boston 15, Mass., includes copper, nickel, iron, chromium, manganese, lithium, sodium, magnesium, calcium and zinc all of which are easily vaporized and produced in pure form.

Existing equipment permits melts from a few grams up to several hundred pounds capacity at pressures between 10^{-6} and 10^{-3} mm. Hg. Upon request, additional technical data and, in some cases, samples of vacuum treated metals may be obtained for experimental purposes.

G. E. Announces Two New Tubes

A new forced-air-cooled transmitting tube, Type GL-5518, for use as a class C radio-frequency amplifier and oscillator, and a three-electrode transmitting tube, Type GL-5C24, for service as class A and AB_1 audio-frequency amplifier and modulator have been announced by the Tube Division, Electronics Department, General Electric Co., Schenectady 5, N. Y.

New Chairman of Parts Association

Roy S. Laird, Vice President and Sales Manager of Ohmite Manufacturing Co., Chicago, was recently elected Chairman of the Association of Electronic Parts and Equipment Manufacturers. Mr. Laird succeeds J. A. Berman of Shure Bros.

Les Thayer of Belden Manufacturing Co., was elected Vice-Chairman; Miss H. A. Staniland of Quam-Nichols was re-elected Treasurer; and Ken C. Prince was re-elected Executive Secretary.

Miniature Cathode Tubes

Two new miniature cathode type R-F amplifier tubes, the 6BD6 and 12BD6 are now being produced by Raytheon Manufacturing Co., Newton, Mass. Designed to replace bulkier or obsolescent tubes, these new tubes are the electrical equivalent of the 6SK7 and 12SK7.

Outstanding features of these tubes, include a very desirable and practical remote cut-off characteristic, zero-bias operation without cathode resistors, proper operating characteristics with or without series screen-dropping resistor, and production of maximum useable stable stage gain, regardless of mutual conductance, at radio and intermediate frequencies.

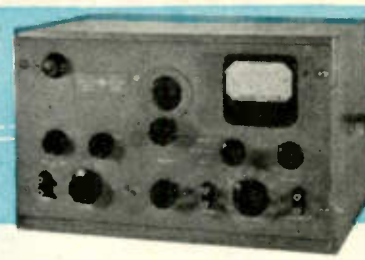
(Continued on page 32A)

LABORATORY INSTRUMENTS FOR SPEED AND ACCURACY

201B AF OSCILLATOR

Meets every requirement for speed, ease of operation, accuracy and purity of wave form in FM and other fields where high fidelity is important.

Frequency range from 20 Cps to 20 Kc. Up to 3 watts power into 600 ohm resistive load with distortion of less than 1%. (Distortion not more than ½% at 1 watt output.) Frequency control is accurately obtained by direct or a 6-1 vernier tuning over a large illuminated, no-parallax dial. Price $190.00 FOB Palo Alto.



330B DISTORTION ANALYZER

Unusually valuable for measurement through the audio spectrum in broadcast, laboratory or production problems. Measures "total" distortion at any frequency from 20 Cps to 20,000 Cps, and will accurately make noise measurement of voltages as small as 100 microvolts. Linear r-f detector makes possible measurement direct from modulated r-f carrier. May be used as voltmeter for measuring voltage level, power output, amplifier gain; or serves as high-gain, wide-band stabilized amplifier with maximum gain of 75 db. Price $375.00 FOB Palo Alto.

One year of -hp- achievement

In one single year since the war's end, *-hp-* has brought you five important new precision instruments. All are now in use in laboratories, factories, electrical and electronic installations around the world. Each represents a vital contribution to the field of electrical measurement. Each is an example of how *-hp-* engineering anticipates the rapid strides of modern science.

Soon *-hp-* will announce significant new instruments to further broaden the field of electrical measurement. Meantime we are now able to make immediate delivery on most *-hp-* instruments. Send your order now!

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1304D PAGE MILL ROAD • PALO ALTO, CALIFORNIA

410A VACUUM TUBE VOLTMETER

Measures voltage over wide frequency range (from audio to microwave regions) at high impedance. High input impedance and low shunt capacity makes possible testing video and VHF amplifier circuits without disturbing circuit under test. *ac measurements:* Six ranges, full-scale readings from 1 to 300 volts. Input impedance 6 megohms in parallel with 1.3 $\mu\mu$fd. Frequency response 20 Cps to 700 Mc, ±1 db. *dc measurements:* Seven ranges, full-scale readings from 1 to 1000 volts. Input impedance 100 megohms, all ranges. *Resistance measurements:* Seven ranges, mid-scale readings, 10 ohms to 10 megohms. Price $210.00 FOB Palo Alto.

710A POWER SUPPLY

Ideal power supply for general, laboratory, or production use. Delivers any required voltage between 180 and 360 volts, with approximately 1% variation for output currents of from 0 to 75 ma. Maximum current 100 ma. Line voltage variation of ±10% causes less than 1% change in output voltage. Total noise and hum output is less than .005 volts. Supplies up to 5 amps at 6.3 volts ac for heating filaments. Either positive or negative terminal may be grounded. Price $75.00 FOB Palo Alto.

450A AMPLIFIER

A stable, wide-band, general purpose laboratory instrument. 40 db or 20 db gain of unusual stability, low phase shift. Frequency response flat within ½ db between 10 and 1,000,000 cycles. Input impedance 1 megohm shunted by 15 $\mu\mu$fd. Internal impedance less than 150 ohms over entire range. Fully operated from 115 volts, 60 cycles AC power supply. Can be used with 400A Vacuum Tube Voltmeter to measure voltages as low as 50 microvolts. Price $125.00 FOB Palo Alto.

Power Supplies • Frequency Standards • Amplifiers • Electronic Tachometers • Frequency Meters • UHF Signal Generators • Square Wave Generators • Noise and Distortion Analyzers • Audio Signal Generators • Attenuators • Audio Frequency Oscillators • Wave Analyzers • Vacuum Tube Voltmeters

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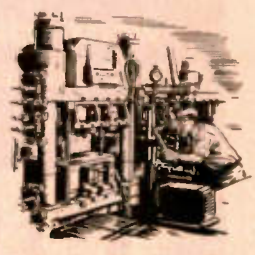
*DESIGNING
. . . Artistic visualization. Creative engineering. Practical planning for efficient plastics production.

*PRODUCTION
. . . Complete machine shop facilities for manufacturing dies, molds and tools.

*LAMINATING
. . . Sheets, rods, tubes. Standard NEMA grades; over 700 special grades.



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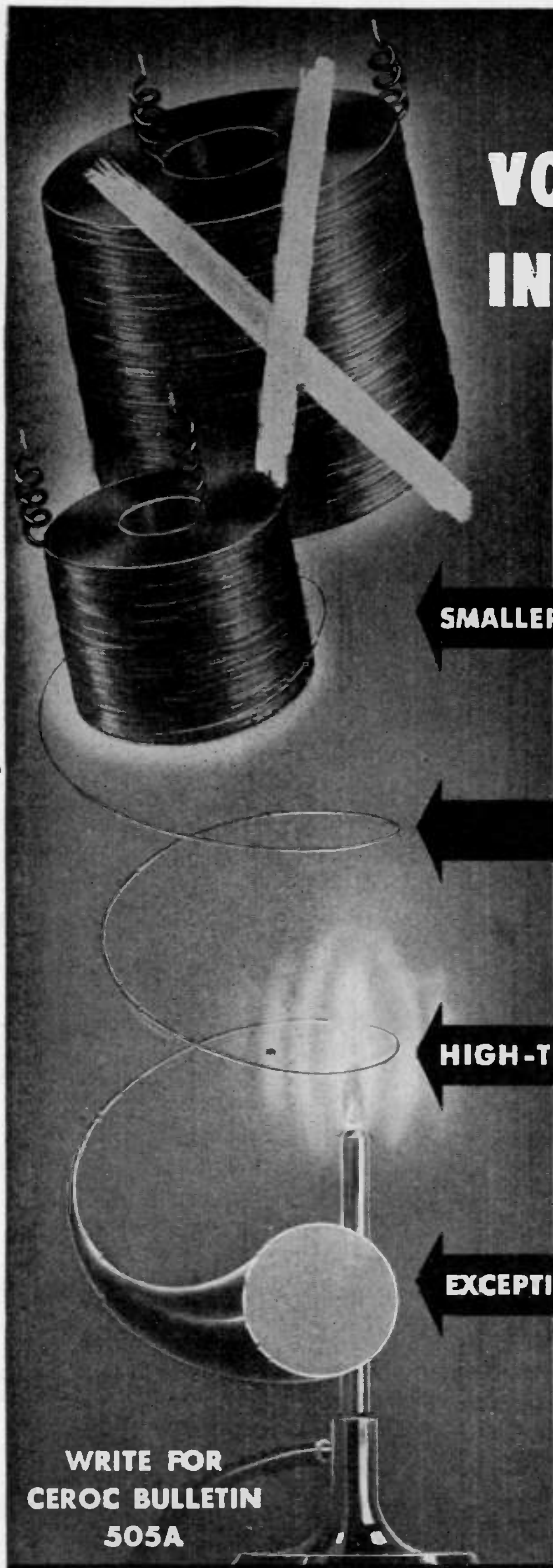

WRITE FOR
CEROC BULLETIN
505A

RAYTHEON

Announces a New High-Gm Miniature Pentode

Announcement of Raytheon type 6AH6 makes available a miniature cathode-type high-Gm pentode specifically designed for application in wide-band amplifiers. The availability of this tube makes possible space and weight reduction of television cameras, television receivers, radar amplifiers, and other multi-tube equipment.

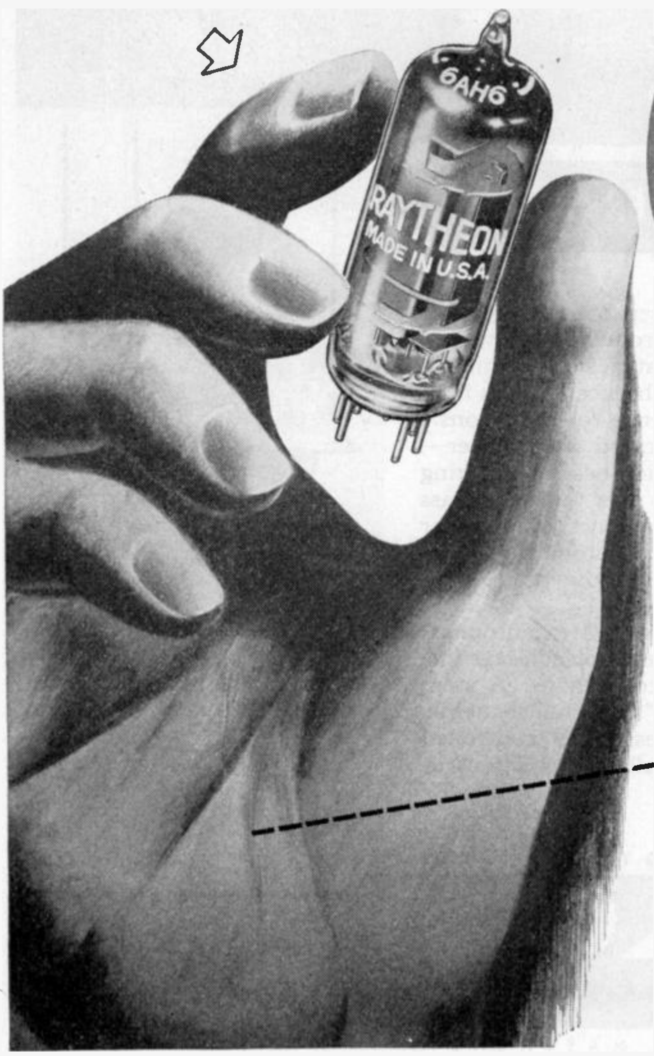
The excellence of Raytheon design for type 6AH6 contributes several desirable performance features, including a plate family characterized by a sharp "knee" at very low plate voltages. Thus increased voltage output and reduced distortion are obtained compared to other tubes of equal transconductance. The low input and output capacitances also allow greater stage gain for a given band-width, and greater band-width for a given stage gain.

DESCRIPTIVE DATA
TYPE 6AH6
BULB: GLASS T-5½
CHARACTERISTICS

Heater Voltage	6.3 volts
Heater Current	0.45 amp
Plate Voltage	300 volts
Grid No. 2 Voltage	150 volts
Cathode Resistor	160 ohms
Plate Current	10 ma
Grid No. 2 Current	2.5 ma
Plate Resistance	0.5 megohm
Transconductance	9000 umhos
Grid No. 1 Bias for 10 ua plate current	—7 volts

TYPE 6AH6
BASE: MINIATURE BUTTON 7-PIN
CAPACITANCES (μμf)

	WITHOUT SHIELD	SHIELDED
Grid No. 1 to Plate	0.030 max.	0.020 max.
Input	10.3	10.5
Output	2.0	4.0



Gm-9000

Type 6AH6

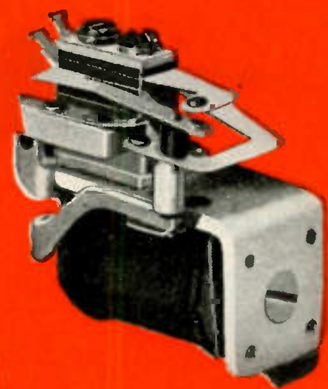
RAYTHEON

Excellence in Electronics

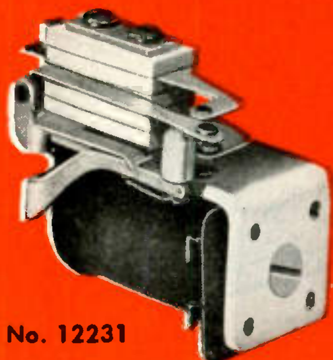
RAYTHEON MANUFACTURING COMPANY
RADIO RECEIVING TUBE DIVISION
Newton, Mass. • Chicago • Los Angeles

ARC

miniaturized RELAYS *with Steatite Insulation*

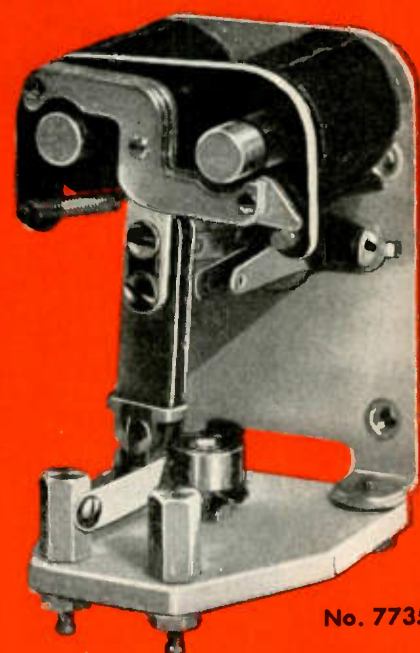


No. 11638



No. 12231

(SHOWN OVERSIZE FOR CLARITY)



No. 7735

Originally designed for use in aircraft equipment, these MINIATURE relays give completely dependable operation under extreme conditions of vibration, humidity and temperature.

The Steatite insulation and general construction of these relays makes them inherently suitable for switching circuits requiring permanently low leakage, for switching certain high frequency circuits, and for any application where a compact, light weight, yet sturdy relay is required. Particular attention has been paid to design of relays that will not "chatter" under vibration even in the un-energized position.

The antenna changeover relay shown is of unique design and provides the wide contact spacing and positive action necessary for this special purpose, for a weight of only 0.2 lb.

The other small relays are provided in the contact combinations illustrated at right, with maximum overall dimensions of 1¼" x 11/16" x 1¼" and a maximum weight of 0.07 lb.

A.R.C. NO.	RATED D.C. OPERATING VOLTAGE	D.C. RESISTANCE	CONTACT ARRANGEMENT
11975	14	90	
12232	28	300	
11914	14	90	
12231	28	300	
11638	28	300	
7735	28	112	

For price and delivery information, write

AIRCRAFT RADIO CORPORATION

708 MAIN STREET BOONTON, NEW JERSEY

ARC

● Aerovox silvered-mica capacitors are designed for the most critical applications requiring precise capacitance values and extreme stability. Although otherwise similar in external construction and dimensions to the smaller molded bakelite units, they are encased in molded XM low-loss *red bakelite* for immediate *silvered-mica* identification.

A silver coating is applied to the mica and fired at elevated temperatures. This insures not only a positive bond but permanent stability of the capacitance with respect to time, temperature and humidity. Units are heat-treated and wax-impregnated externally for ultimate protection against moisture penetration.

Ideal for use in circuits where capacitance must remain constant under all operating conditions. These capacitors are specifically designed for use in push-button tuning, oscillator padding circuits, fixed tuned circuits, and as capacitance standards, etc., where accuracy and stability are prime considerations.

● Write for literature . . .

Average positive temperature coefficient of only .003% per degree C.—a remarkably low value.

Excellent retrace characteristics; practically no capacitance drift with time; exceptionally high Q.

Available in three types, 1000 v.D.C. test: Type 1469, .000005 to .0005 mfd.; Type 1479 (illustrated), .0001 to .001 mfd.; Type 1464, .00075 to .0025 mfd., and .001 mfd. in 600 v. D.C. test.

Standard tolerance plus minus 5%. Also available with tolerances of plus/minus 3%, 2% and 1%.

Minimum tolerance for capacitances up to and including 10 mmf. (.00001 mfd.) plus/minus ½ mmf. Minimum tolerance available for all other capacitances, plus/minus 1% or plus/minus 1 mmf., whichever is greater.

• • •

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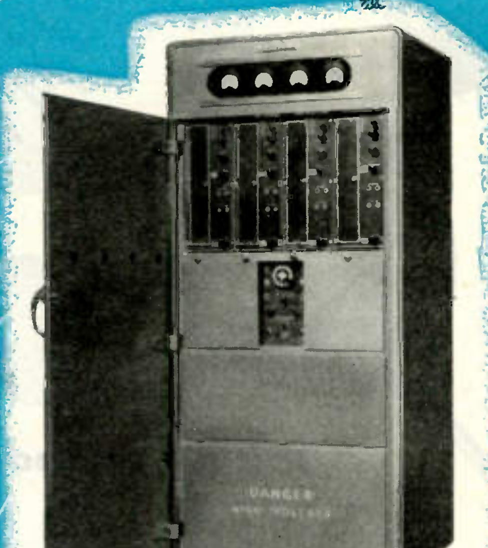


DU MONT
Cathode-ray Tube
HEADQUARTERS
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INDUSTRIAL
TELEVISION
RESEARCH
Applications
If it's a cathode-ray tube, DU MONT has it!
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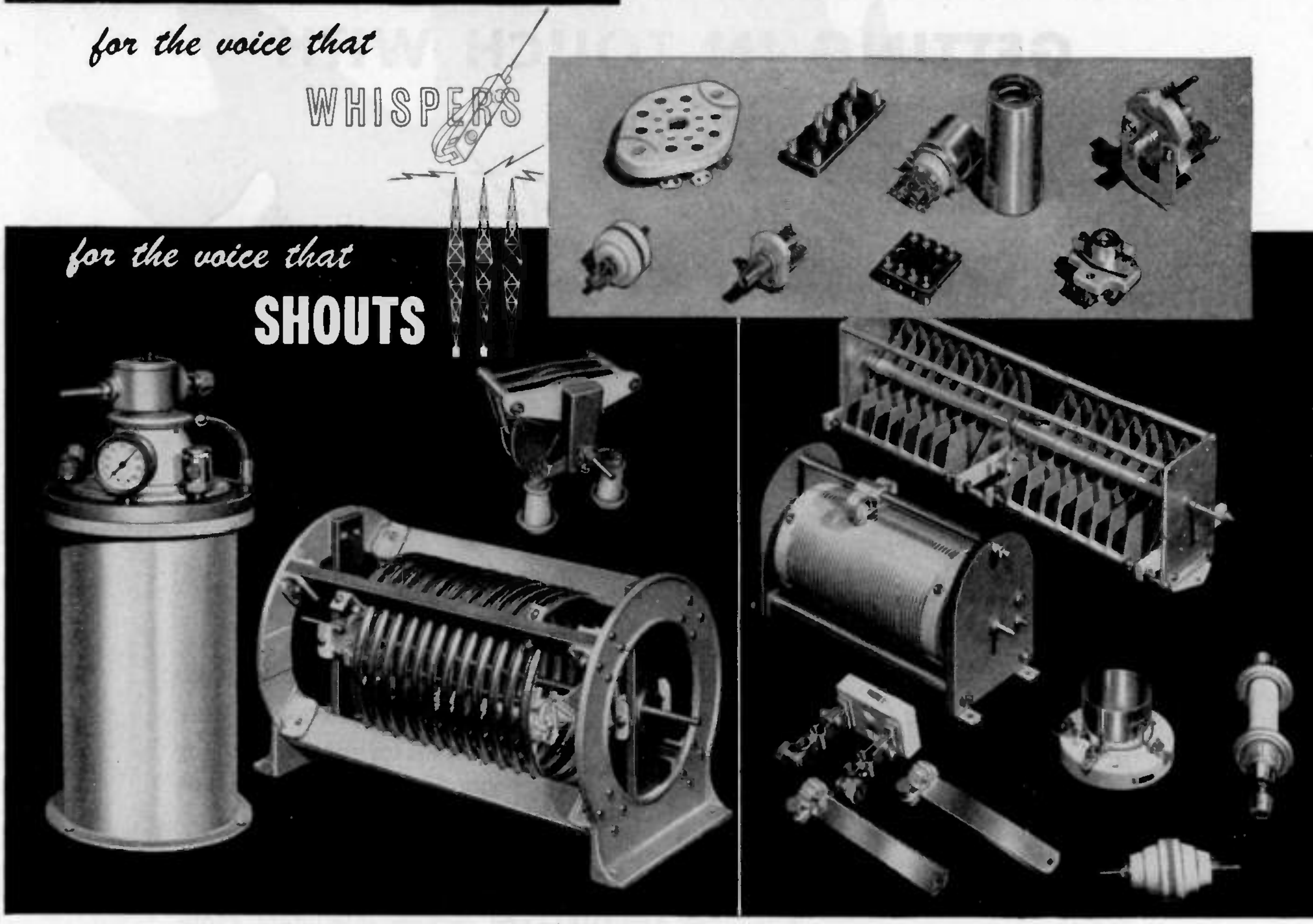
JOHNSON COMPONENTS

for the voice that WHISPERS

for the voice that **SHOUTS**



If you design or build electronic equipment no smaller than a handy-talkie, no larger than a 50 KW transmitter there are JOHNSON components "your size." Many of the small parts above find application in circuits operating at battery voltages. The miniature socket for instance is a modification of a predecessor that floated down over Europe in a handy-talkie with the paratroopers. They're catalog items with the exception of the terminal boards which typify JOHNSON ability to manufacture special assemblies quickly, easily and economically. The miniature condenser is an inch and half overall, has .015" spacing, 12 mmf. maximum and 3 mmf. minimum capacity. On the large side of the condenser family are the pressurized nitrogen-dielectric condensers offering RMS voltage ratings to 30,000 V capacities to 10,000 mmf., and highest capacity to mounting space ratios. Similar comparisons might be made with the other JOHNSON components.

Between the large and small above there's a big JOHNSON line from which to choose. Check the list below for parts you need. You'll find them carefully designed, skillfully manufactured. For more information write department W today.

Johnson Products Include

Condensers • R. F. Chokes • Connectors • Pilot and Dial Lights
Directional Antenna Equipment • Inductors • Q Antennas • Plugs & Jacks
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JOHNSON
a famous name in Radio

E. F. JOHNSON CO., WASECA, MINNESOTA

■ Seal up a stream of electrons in a vacuum tube... and you have a space-defying genie that vitalizes industry ...and can save countless lives!

■ As far back as 1930 the Sperry Gyroscope Company put electronics to work . . . introducing electronic control for the Sperry Gyro-Compass.

■ From then on electronics was employed whenever it could extend the usefulness and performance of Sperry products—as in automatic pilots, gun fire control devices, navigation instruments, both aeronautical and marine. And in 1939, came the Klystron, "heart-beat" of Radar.

■ In war, Radar tracked out enemy plane, sub and ship positions, saving numberless lives by advance warning of hostile attack. And today, in peace, Radar brings new safety to mankind... plotting aerial and marine operations with pin-point accuracy, through pea-soup weather and over vast distances.

■ Sperry pioneered in helping develop these and many other services for mankind. But "pioneering" isn't enough. And that's why Sperry research and practical applications of electronics go endlessly on . . . in that search for something better which we call *product improvement.*

Sperry Gyroscope Company, Inc.

EXECUTIVE OFFICES: GREAT NECK, NEW YORK • DIVISION OF THE SPERRY CORPORATION

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Aircraft: Gyropilots • Gyrosyn Compasses • Attitude Gyros • Directional Gyros • Gyro-Horizons • Detonation Indicators • Automatic Radio Direction Finders • Instrument Landing Systems • Traffic Control Systems • **Marine:** Gyro-Compasses • Gyro-Pilots • Gyro-Magnetic Compasses • Incandescent Searchlights • Steering Systems • Radar • Loran **Industrial:** Railroad Radio • Microwave Relays • Microline Test Equipment • Klystron Tubes • Strobodyne • Knockometer

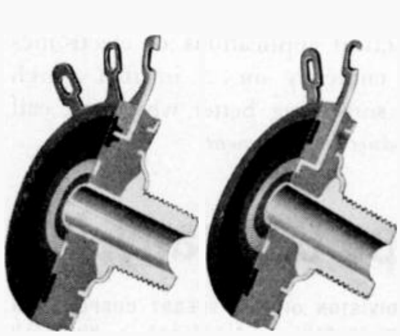
The Bradleyometer Resistor is solid-molded and thick ... not just sprayed film

The heart of an adjustable composition rheostat or potentiometer... like the Type J Bradleyometer ...is the resistor element. If it is a fragile, sprayed film, it cannot hold up satisfactorily under frequent operation, rapid climatic changes, or overload. But if it is a thick, solid-molded ring . . . as in the Type J Bradleyometer...it has long, trouble-free life built into it. And its 2-watt rating has a big safety factor, too.

Type J Bradleyometers can be furnished in single, dual, or triple unit construction. Built-in switch is optional. Let us send you specifications.

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

The resistor element is molded as a single unit, with insulation, terminals, face plate, and threaded bushing. There are no rivets, welded or soldered connections.



During manufacture, the resistance may be varied over its length to provide any resistance-rotation curve. After molding, heat, cold, moisture, or hard use cannot affect it.

ALLEN-BRADLEY

FIXED & ADJUSTABLE RADIO RESISTORS

QUALITY

ANOTHER "EVEREADY" SCOOP

Announcing—

A 300-VOLT 1-LB. BATTERY!

Designed for: photoflash devices (gas-discharge type); radioactivity measurement devices; multiplier-type photocells; small, lightweight insulation testers; and many other low-drain, high-voltage applications.

Again "Eveready" demonstrates its leadership in dry batteries by creating a powerhouse of 300 volts no larger than two king-size cigarette packs! This miniature high-voltage dry battery is unique. It makes "portable" photoflash and similar devices really portable. It opens up untapped possibilities for designing more compact, more salable equipment for all low-drain high-voltage applications.

Secret of this new battery is the famous flat-cell construction found exclusively in "Eveready" "Mini-Max" batteries... a revolutionary "Eveready" battery development that packs unheard-of power into small space. And this special construction means *far longer life* for the battery.

SPECIFICATIONS

Size: L—2 11/16", W—2 11/32", H (overall)—3 15/16". Weight: 1 lb. Voltage: 300. Flush mounted pin jack terminals. Batteries can be used in series for even higher voltages.

FOR COMPLETE DETAILS of this new "Eveready" triumph, write for Battery Engineering Bulletin No. 4. Engineers at National Carbon Company, Inc., will be glad to assist you in the design of devices to take advantage of the light weight and compactness of this powerful battery.

EVEREADY
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MINI-MAX

The registered trade-marks "Eveready" "Mini-Max" distinguish products of National Carbon Company, Inc.

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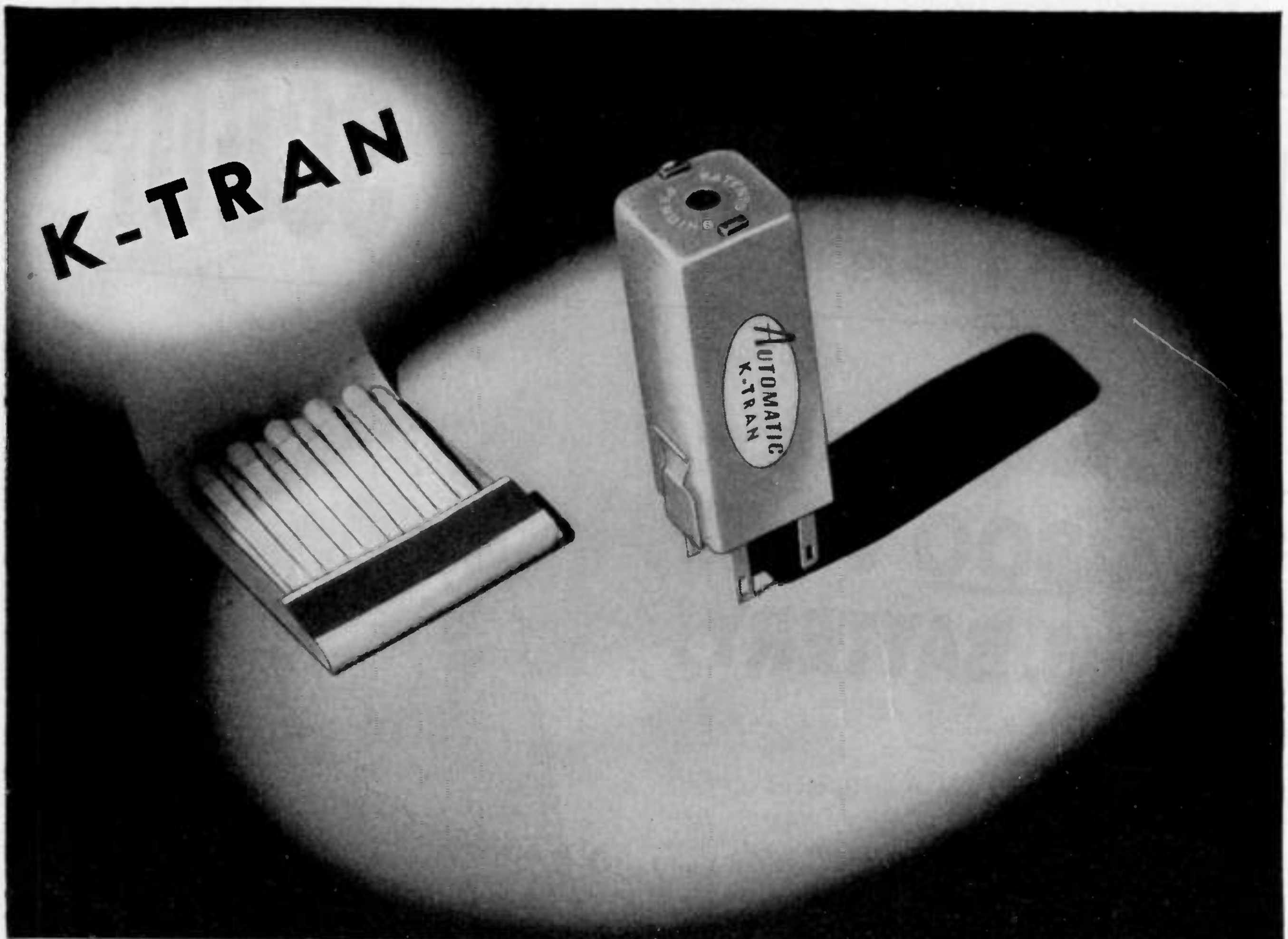
K-TRAN
AUTOMATIC
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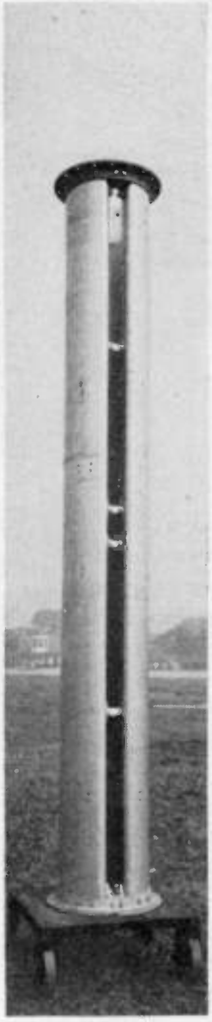
NEWS and NEW PRODUCTS

December, 1946

(Continued from page 14A)

Pylon FM Antenna

A new cylindrical FM antenna, revolutionary in its simplicity of design and principal, providing higher gain height for



height than any previous antennas, has been developed and placed in production by the RCA Engineering Products Department, Radio Corporation of America, Camden, N. J.

Known as the "Pylon" antenna, this new FM radiator is a single-element, mechanically-rigid, self-supporting structure. Unlike all previous types of FM antenna, this new antenna requires no additional means of support or mounting, nor are there any arms, loops or circular elements required with their attendant mounting and connection problems.

Because of this, it was pointed out, erection of the Pylon is extremely simple. All that is necessary is merely to bolt the bottom flange of the cylinder to the building, tower or other supporting structure which provides the necessary elevation and where high gain is needed for an FM station, additional sections can be stacked on top of each other by merely bolting together.

Multi-Wire Connectors

Two new multi-wire connectors have been recently announced by Alden Products Company, 117 North Main Street, Brockton, Mass., and The Winchester Company, 6 East 46 Street, New York 17, N. Y. Both units are weather-proof.

The Alden unit is a locking-ring type providing cable strain relief by means of a special metal shell.

The Monoblock unit of the Winchester Company is particularly adapted to limited space applications in two sizes of 12 and 18 contacts.

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

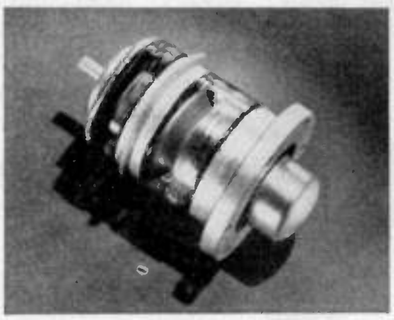
Electronic Voltmeter

Instrument Electronics, 253–21 Northern Blvd., Little Neck, L.I., N.Y., announce their new Model 45 Electronic Voltmeter. The meter has a range of from .0005 to 500 volts at frequencies from seven cps to 1.6 Mc.

This meter is suitable for all voltage measurements in the vibration, audio, supersonic and broadcast frequencies bands, the manufacturer states. Line voltage variations from 105 to 125 voltages will vary the readings on the logarithmic scale by less than 1%, at all frequencies within the specified range.

G. E. Transmitting Tube

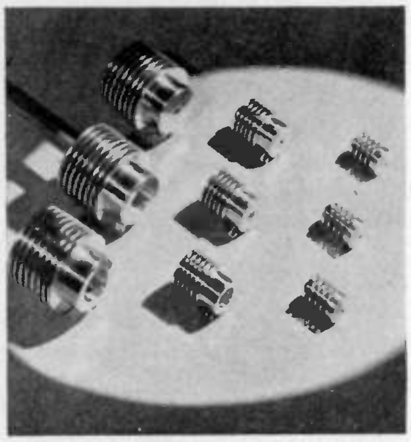
A new transmitting tube, triode type GL-9C24 has been announced by the Tube Division, General Electric Company, Syracuse, N. Y. Designed particularly for application in a grounded-grid circuit as a class B radio-frequency amplifier and a class C r-f amplifier and oscillator, the tube may be used in television and FM operation at the higher frequencies.



The anode is water-cooled and capable of dissipating five kilowatts. Actual 220-megacycle tests under broad-band and synchronizing peak condition show a useful power output of 3.4 kilowatts at a DC plate voltage of 4000 volts.

Heat Dissipating Connectors

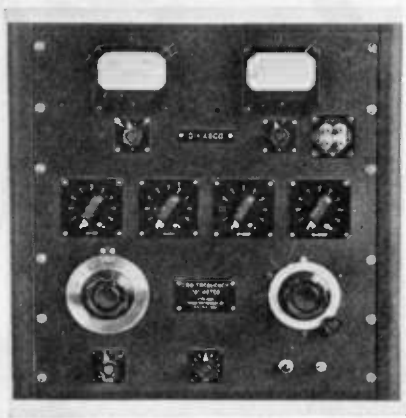
Eitel-McCullough, Inc., of San Bruno, Calif., announces that their HR Heat Dissipating Connectors are now available. These connectors are used to make elec-



trical connections to the plate and grid terminals of vacuum tubes, and, at the same time, provide efficient heat transfer from the tube element and glass seal to the air. The HR Connectors aid materially in keeping seal temperatures at a safe value, and are machined from solid dural rod.

Low Frequency "Q" Indicator

A completely self-contained "Q" indicator for use in the 50 to 50,000-cycle range incorporating a precision tuning condenser and a high stability vacuum tube type voltmeter of special design has been announced by Freed Transformer Company, Inc., 72 Spring Streeto, New Yrk, N. Y.



This new unit, No. 1030, will directly measure circuit "Q" with an accuracy of approximately 6% for its designed frequency range. A balanced voltmeter circuit assures stability of "Q" measurements and keeps to a minimum fluctuations caused by line voltage variations.

(Continued on page 48A)

AVR-22

IT'S NEW!

ANOTHER COMPLETE AIRCRAFT RADIO SYSTEM by RCA...

AVR-22 AIRCRAFT RECEIVER

Less than half ATR size! Weighs only 21 lbs. complete. Designed to operate with Model AVA-62 Loop antenna for aural direction finding.

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AVIATION SECTION

RADIO CORPORATION of AMERICA

ENGINEERING PRODUCTS DEPARTMENT, CAMDEN, N.J.

In Canada: RCA VICTOR Company Limited, Montreal

RCA PREFERRED TYPE POWER TUBES

QUICK-REFERENCE POWER-FREQUENCY TABLE

Type No.	Class	Maximum Input Power (Watts) CCS Unmodulated Class C Ratings at:											
		1.6 Mc.	7.5 Mc.	15 Mc.	25 Mc.	50 Mc.	75 Mc.	110 Mc.	150 Mc.	200 Mc.	250 Mc.	300 Mc.	600 Mc.
9C21	Triode	150000	150000	150000	105000								
9C22	Triode	100000	91000	80000	70000								
9C25	Triode	40000	40000	40000	40000	25000	25000	25000					
9C27	Triode	40000	40000	40000	40000	25000	25000	25000					
892	Triode	30000	22500	17000									
892R	Triode	18000	13500	10500									
889-A	Triode	16000	16000	16000	16000	16000	14000	11000	8000				
889R-A	Triode	16000	16000	16000	16000	13500	10000						
8D21*	Tetrode	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	
7C24	Triode	5000	5000	5000	5000	5000	5000	5000					
833-A	Triode	1800	1800	1800	1750	1500	1200						
6C24	Triode	1500	1500	1500	1500	1500	1500	1500	1500				
4-125A/4D21	Tetrode	500	500	500	500	500	500	500	500	425	335		
8000	Triode	500	500	500	500	400	300						
813	Beam Power	360	360	360	360	300							
8005	Triode	240	240	240	240	195							
828	Pentode	200	200	200	200	160	130						
811	Triode	155	155	155	155	155	125						
812	Triode	155	155	155	155	155	125						
826	Triode	125	125	125	125	125	125	125	125	125	125	100	
829-B*	Beam Power	120	120	120	120	120	120	120	120	120	105		
8025-A	Triode	75	75	75	75	75	75	75	75	75	75	75	75
815*	Beam Power	60	60	60	60	60	60	60	55	40			
807	Beam Power	60	60	60	60	60	50	40					
2E24†	Beam Power	40	40	40	40	40	40	40	33				
832-A*	Beam Power	36	36	36	36	36	36	36	36	36	32		
2E26	Beam Power	30	30	30	30	30	30	30	25				
802	Pentode	25	25	25	25	20	16						

*Twin type—input values per tube for push-pull operation.

†Recommended only for highly intermittent applications. Input values are ICAS ratings.

The accompanying table of ratings vs. operating frequency provides the design engineer with a simple and rapid means of choosing the most suitable RCA tubes to meet the power and frequency requirements of equipment in the design stages.

Technical Literature

Detailed data on all the types listed are provided in the RCA HB-3 TUBE HANDBOOK. Technical bulletins covering tube types in which you are interested will be sent on request.

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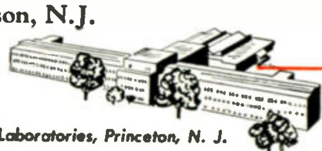

RCA Laboratories, Princeton, N. J.
THE FOUNTAINHEAD OF MODERN TUBE DEVELOPMENT IS RCA

TUBE DEPARTMENT

RADIO CORPORATION of AMERICA

HARRISON, N. J.

PROCEEDINGS OF THE I.R.E.

AND

WAVES AND ELECTRONS

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PROCEEDINGS OF THE I.R.E.

INSTITUTE NEWS AND RADIO NOTES

WAVES AND ELECTRONS SECTION

Bikini Observations and Their Significance*

HARADEN PRATT†, FELLOW I.R.E., AND ARTHUR VAN DYCK‡, FELLOW I.R.E.

On rare occasions, events of transcendent importance are described in a paper of corresponding significance. The following presentation, prepared by two Past-Presidents of The Institute of Radio Engineers who were official United States scientific observers of Operation Crossroads, is a contribution of this unusual sort. It is most earnestly commended to the thoughtful attention of the readers of the PROCEEDINGS OF THE I.R.E. and for such comments and actions by them as may further the aims which it outlines.

THE OBSERVERS of Operation Crossroads were accommodated on ships of the general communications type. Designed to carry large military, naval, and air staffs in amphibious operations, they provided ideal quarters for this purpose. The observers were of several kinds: scientific men from the United States and the United Nations, United States congressional representatives, officers of the United States War and Navy Departments, and representatives of the press. In spite of the size and complexity of Operation Crossroads, it was executed in most efficient fashion throughout, and the excellent handling of observers was but one example of the general effectiveness of the organization, which was under the able command of Vice Admiral Blandy.

The U.S.S. *Panamint*, to which we were assigned, arrived at Bikini lagoon on the morning of June 29 and immediately steamed to an achorage a short distance from Bikini Island by moving very slowly through the entire target array of some 72 ships. The sight was impressive in all respects. A mighty fleet was anchored row upon row on the azure waters of an immense tropical lagoon fringed with palm tree islands, waiting for the awesome test scheduled only two days away. Battleships, cruisers, carriers, destroyers, submarines, transports, and ships of other smaller types—even to a concrete drydock—were variously grouped around the target's bull's-eye to which the eye of the observer continually reverted, namely, the majestic battleship *Nevada*, conspicuous in bright orange paint and white turret tops and guns, the better to guide the bombardier on the fateful day.

* Decimal classification: 623.452.9. Original manuscript received by the Institute, November 11, 1946.

Paper presented in New York City, November 6, 1946, at a joint meeting of The Institute of Radio Engineers, The American Institute of Electrical Engineers, and The Radio Club of America.

† Mackay Radio and Telegraph Company, New York, N. Y.

‡ Radio Corporation of America, New York, N. Y.

It was obvious that these ships had been prepared for this special event since they were disposed in a pattern intended to reveal maximum information on damage at all distances. Their decks were fitted with all kinds of equipment and materials of war to be subjected to the explosion. Each ship had graduated scales painted on bow and stern so that settlement could be noted from time to time through observation from aircraft. Even the islands bore evidence of the vast preparation that preceded our visit, as several steel towers to accommodate cameras and other instruments were easily visible.

That afternoon we visited the *Nevada*, the Japanese battleship *Nagato*, and the carrier *Independence*, where we saw the large number of test specimens mounted on their decks. These included samples of clothing, food, armor plate, airport fuel trucks, medical supplies, airplanes, and hundreds of other items of military weapons and supplies. The *Nagato*, commissioned about 1921, was of particular interest with her war wounds of the two direct hits from aerial bombs, including the skip bomb that went right through the ship via Admiral Yamamoto's quarters.

Long studies of Bikini July weather indicated that perhaps as many as twenty days could elapse before a suitable one for the drop would arrive. Besides adequate visibility it was required that the wind blow in the same direction from sea level to 20,000 feet, so that radioactive products of the atomic fission would move away from all observers and not endanger them in the event of rain. However, on June 30 such weather was predicted for July 1, and the fleet of some 140 attending vessels steamed out of the lagoon, maneuvering during the night to be at their assigned locations for the big event at 8:30 the next morning.

We on the *Panamint* saw the blast from the bridge deck through very dark special goggles at a point about twenty miles from the *Nevada*. Not being able at this distance to see any of the target fleet, many of us were not looking directly at the correct spot and so missed the initial point of flash. By the time eyes had moved over, the burst had already become a disk somewhat larger than the sun and considerably brighter, a conclusion made possible by being able to glance at the sun several times before the ship's public-address system announced "bomb away."

The disk of intense light was immediately blotted out by the instantaneously formed luminous dome or hemisphere of incandescent gases which rested on the water, covering much of the target area. Quick loss of luminosity occurred, and with bare eyes we viewed the majestic column of atomic cloud with its mushroom top rise and shoot several thousand feet skyward in a matter of seconds. We estimated that this structure rose to a total of some 38,000 feet, displaying from the start interesting shades of pinkish colors against a fleecy white. The yellowish aspect of previous atomic explosions, ascribed to dirt and debris, was, of course, absent at Bikini.

By eleven that morning, we had moved up to the reef and examined the target fleet through binoculars while seeing at the same time yellow-colored drone boats darting about picking up water samples to test for radioactivity. These boats were remotely controlled from a distant destroyer with air units observing and directing. Test results were favorable for certain parts of the lagoon and our ships took anchorage there soon after lunch. Here we were able to survey the fleet clearly and note the many wrecked superstructures. The outstanding spectacles were the Japanese cruiser *Sakawa* with a list, down at the stern, and a completely wrecked top, and the carrier *Independence* with bad fires which culminated toward evening in spectacular explosions leaving the ship a shambles. The *Sakawa* turned turtle and sank the next morning.

Interesting and spectacular as all these events were, the full realization of the enormous significance of what had taken place unfolded rather slowly during succeeding days as we visited and examined ship after ship. Lessened radioactivity enabled ships to be boarded 48 hours after the burst. Within a 3/4-mile radius, exposed wood was scorched black, crates and boxes were burned, and the *Nevada's* after deck, hit by the blast at an angle of about 25 degrees, was crushed down and blackened. Her funnels were pushed into her superstructure and the airplane crane on her stern bent double. It should be explained that, after striking bull's-eyes on many practice runs, the bombing plane had the hard luck, on the real drop, of missing the *Nevada* by some hundreds of feet, a sore disappointment to the Army Air Forces.

Conditions were the same on the *Arkansas*, and worse on the *Pensacola* which was within a half-mile radius. All these vessels' decks and superstructures were a mass of wreckage, with bent bulkheads, twisted railings, smashed doors, stacks down, antenna gear deformed or broken—not to speak of peeling paint from the heat wave and the damaged or burned-out specimens placed on their decks. The blast wave even penetrated below, wrecking furnishings and doing other damage in spots here and there. Many vital items were seriously damaged, such as bulkhead-mounted motor-control cabinets, the switches and other parts of which were broken loose and completely inoperative. Broken castings in quantity taught that naval ships of the future must avoid the use of metal fabricated in brittle forms.

It was unfortunate that our public was misled during the weeks preceding the tests by statements appearing in the press forecasting dire results and the possible unleashing of forces of nature such as earthquakes, tidal waves, and volcanic eruptions. It must be remembered that the effects of explosions diminish very rapidly with distance, and while the atomic holocaust sank and wrecked vessels up to one-half mile, damage to ships beyond one mile was relatively light. Heat, blast, and wave action at Bikini Island three miles away left almost no visible traces. Even direct blast and heat damage from huge volcanic explosions such as Krakatoa and Katmai extended over only small areas. Certain excited spectators, therefore, had no logical basis for reporting disappointment because Bikini trees were not uprooted or because the blast at twenty miles did not blow them off their feet.

It must be remembered that, while five ships were sunk in the air test and about nine sunk plus two beached in the underwater test, conclusions as to the power of atomic bombs should not be based on the number of ships sunk. Obviously, if the whole fleet had been closely bunched most would have been sunk, whereas if widely dispersed not more than one such casualty would have occurred.

However, all these arresting phenomena, significant in their seriousness as they are, represent only the effect of heat and explosive action arising from the concentration of stupendous power at a single point. The effects of radioactive radiations, primarily neutrons and gamma rays, constitute the new feature which justifies the appellation of "Poison Bomb" as conveying the real meaning of this colossal development. Even though radiation diminished so fast after the first test as to enable ships to be safely visited a few hours later, it is doubtful whether more than a few could have survived aboard had the ships been manned when the bomb was dropped, even though the bulk of the crews might have lived long enough to render ships operative and resist postexplosion attack.

Any doubts as to the sweeping nature of the poison effect which may have existed were removed after the second atom bomb was exploded below the surface of Bikini lagoon. Millions of tons of sea water hurled skyward over one mile in a column almost one-half mile in diameter, and was heavily contaminated with the fission products estimated as equivalent to hundreds of tons of radium. In the first test these products distributed in the atmosphere and were dispersed by the winds. This death-laden water in the second test fell directly on all ships in the lagoon and engulfed some in waves 70 to 100 feet high. This resulted in radioactive products being washed down ventilators, pipes, funnels, and scuppers, in saturation of all topside hamper, and in penetration to hidden places such as circulating systems, pumps, and evaporators.

Even ships not in the target fleet became dangerously contaminated by entering affected lagoon areas afterwards. Many of the surviving vessels are still uninhabitable and others present vexatious problems of reconditioning because of gamma rays coming from materials lodged in the scale and incrustations inside sea-water piping.

Much has been said as to whether the tests were necessary and their cost justified, even though the cost was less than the value of a single modern battleship. Our considered opinion is that the tests were indispensable. Aside from arguments that scientists might fairly well predict results, and apart from the tremendous value of the precise technical information acquired, the mere holding of the operation under controlled conditions with many observers from all walks of life was of incalculable value to all mankind because the impact of the atom bomb reaches human beings everywhere. And there is no substitute for actual results indisputably to drive home the facts.

The significance of the Bikini tests is clear and powerful. Nevertheless, it has been the universal experience of the United States observers, on returning from Bikini, that people with whom they have discussed the matter have been uncertain as to the significance of the tests and of the atom bomb generally. We have even found many people who are unwilling to talk or think about the subject, saying that it is just too horrible to contemplate. We would like to convince such people, and all people, that the atom bomb not only is horrible, but that it is so terrible that something must be done about it. That something is not to hide our heads in the sand—it is that we must insure ourselves against its use. And that means we must somehow prevent all war in the future.

The facts are very clear, and the best presentation may be merely to list them in simple language.

An atom bomb of the present type, exploding in the air, destroys everything within about one-quarter mile, does very heavy damage to one-half mile, and heavy damage to one mile. Beyond one mile, the degree of damage depends upon the character of structures. Windows and light structures will be shattered at several miles.

An atom bomb of the present type kills practically all the human beings within one-quarter mile, a very high percentage of those within one-half mile, and a great many of those within one mile or more.

The present-type bomb, bursting in the air over New York City, would blow out every window within one or two miles and would knock off most of the roof structures and brick and stone facings of buildings, particularly skyscrapers. Casualties from glass and falling debris would be high. Fires from short circuits, broken gas mains, and other causes would be numbered in hundreds.

The present-type bomb, bursting under the water in New York City, would destroy subways, and would render uninhabitable for months an area of at least ten square miles. Each seaport city of the country would be similarly exposed.

The atom bomb is not the only new weapon of vastly increased destructiveness. The guided missile, like the German V-1 and V-2, is another.

The power and destructiveness of weapons has been increasing rapidly for the last 100 years. World War I saw the first wide use of high explosives.

World War II achieved vast destruction. Most people of the United States do not realize this. The people of London, Coventry, Rotterdam, Warsaw, Stalingrad, Berlin, Tokio, and Pearl Harbor *do* realize it.

World War II dislocated civilization, and might have almost completely wrecked it through destruction of so much of the economic structure of the world. Perhaps it actually has, because we do not yet see a definite path to peacetime normalcy, particularly in Europe and Asia.

A third World War will be vastly more destructive of both economic structures and of human beings. Since World War II was almost enough to destroy civilization, a vastly worse War III is certain to do so.

There is no defense against the atom bomb or against the guided missile, or, of course, against a combination of the two. Defense has never been perfect against any weapon. Against the atom bomb, unless the defense is perfect, it is no defense. Not one German V-2 missile was shot down of the many that approached London. If two or three of them had had atom bombs in them, London would have become an empty shell.

We have now reached that advanced state of civilization wherein we have made it possible for a few uncontrolled members of our society to destroy or to subjugate the rest of us, before we can do anything about it. The fact is that material development has reached a dangerously high level. We have been settling arguments by force from the beginning of man on earth, but usually the side of moral right has been able to marshal enough might to prevail sooner or later.

Now we have a new situation, and there is no protection left in material things. Forts and trenches have failed, the Maginot Line failed, the English Channel failed, the oceans have failed. New weapons pierce even the stratosphere.

All this has been said before. Indeed, it has been said so many times that the thought has become familiar and has lost its true meaning to many people. This complacency is dangerous. These facts mean that a revolution in human affairs has occurred. Hereafter civilization must struggle not to advance, but actually to survive. These are not mere words, they are elementary truths. All this should be obvious to everyone, and particularly to those men charged with the responsibility of government. There was a time, shortly after Hiroshima and Nagasaki, when leaders were alarmed, and earnestly and humbly sought for the right answer. But they quickly recovered from that lapse from diplomatic protocol, and today we see national and international leaders operating in the old-fashioned way, ignoring the new facts of life.

It is necessary now to avoid not only war, but the threat of war and the necessity of preparations for defense in war. Even these latter, without war itself, would largely destroy our free civilization because of the continuous state of a "war of nerves" existence, and the vast changes required in our economic life. Even a moderate degree of preparation for an atomic war would require huge changes in the American way of life.

In past centuries, despots have often declared sudden war on unwary and unprepared peoples. In our time, we have seen Germany do it twice and Japan once. They did not win merely because their tools were not equal to the job of subduing us before we were able, under the spur of our peril and our righteous wrath, to prepare defensive means and offensive retaliation. It took all the resources of Japan to carry out one Pearl Harbor at a time. Now it is different. Now despotic rulers, minded as were those of Germany and Japan, can overnight deal such crushing blows to another nation or nations that recovery and retaliation will be impossible.

Therefore, it is obvious that the only safety is in means which will make it impossible for any nation to attack another.

The only possible safe policy for the future must be one which rests on the law and the conscience of man. Nations must be controlled, as we now control states, counties, cities, and individuals.

The people of *no* country want war. Then how do wars come about? In our time, as almost always in the past, they developed from the ambitions of rulers of countries. One of the greatest virtues of an effective democracy is that the actions of its governing group reflect more nearly the wishes of its people. If all rulers had tenure of office limited to a few years, perhaps the urge to war would be reduced toward the vanishing point.

The outstanding need of the moment is to explain these revolutionary facts and conditions to all peoples and rulers of the world. It will take skill and patience to give the required teaching, particularly in countries where the facilities for information dissemination are not good. It will be difficult, because so many have for so long paid so little attention to moral law and conduct among peoples. But it must be done, if life in the future is to be worthwhile, because there is no other way to avoid cataclysmic horror.

We must have world law and order. That is the simple significance of nuclear fission—and of Bikini.

Browder J. Thompson Memorial

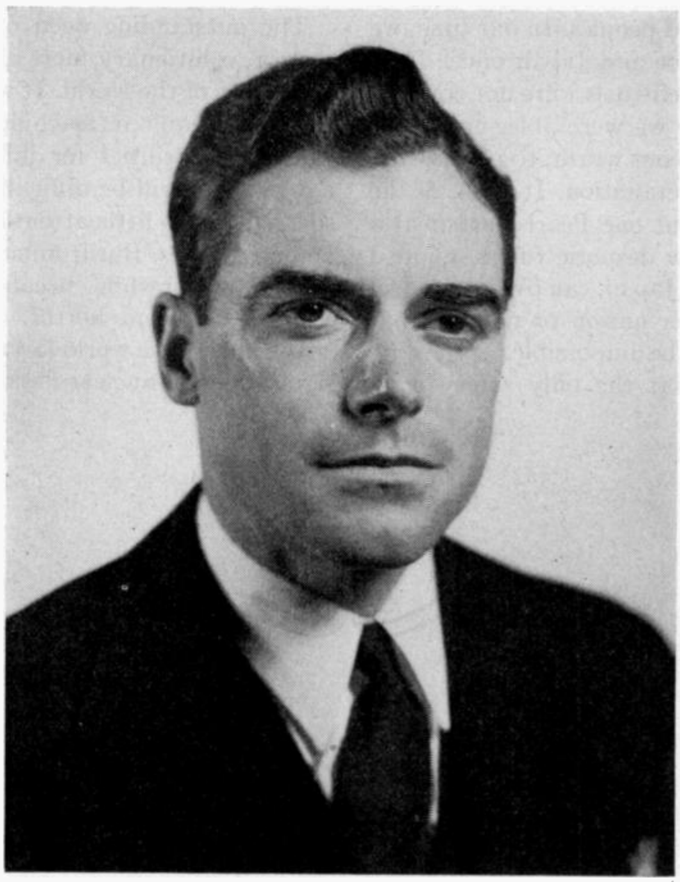
In May, 1945, announcement was made of a plan to establish a memorial to the late Browder J. Thompson.[1] In accordance with this plan, arrangements were made to receive contributions to establish a memorial fund. This fund has subsequently been turned over to the Institute, which has gladly agreed to administer it and to employ the income therefrom to provide an annual award.

By October, 1945, contributions totaling over $4100 had been received,[2] and in November, a check of $4000 for the Browder J. Thompson Memorial Fund was presented to the Institute.[3] In January, 1946, arrangements were completed to make the initial award at the summer Electronics Conference.[4]

The first Browder J. Thompson Memorial Prize was presented to Dr. Gordon M. Lee[5] during the banquet of the I.R.E. Fourth Electron Tube Conference held at Yale University, New Haven, Connecticut, June 27 and 28, 1946.

Now that the memorial is established, the Committee that carried out the plan may be disbanded. As a matter of record, the following statements showing the contributions to the fund and the manner of their disposition are presented. Any future contributions should be made directly to the Institute.

Signed
R. R. Law
Secretary, Memorial Committee



Browder J. Thompson
1903–1944

Princeton, N. J.
September 6, 1946

The Princeton Bank and Trust Company, Princeton, New Jersey, hereby certifies that a total of $5001.03 has been deposited in the account "Browder J. Thompson Memorial Fund."

Signed
Hann M. Thomas
President, Princeton Bank and Trust Co.

The Institute of Radio Engineers hereby acknowledges receipt of $5001.03 from friends of the late Browder J. Thompson.

Signed
William C. White
Treasurer
Institute of Radio Engineers

[1] Proc. I.R.E., vol. 33, pp. 336–337; May, 1945.

[2] Proc. I.R.E., vol. 33, p. 902; December, 1945.

[3] Proc. I.R.E. and Waves and Electrons, vol. 34, p. 43-W; January, 1946.

[4] Proc. I.R.E. and Waves and Electrons, vol. 34, p. 203-W; April, 1946.

[5] Proc. I.R.E. and Waves and Electrons, vol. 34, p. 466; July, 1946.

This fund shall be administered by the Institute in accordance with the provisions outlined in the following specifications:

Specifications for the Browder J. Thompson Memorial Prize

In tribute to the late Browder J. Thompson, who gave his life in service to his country, friends have established a Memorial to commemorate his interest in science and his many contributions in the field of radio and electronics. In view of his long and intimate association with The Institute of Radio Engineers, contributions of friends were turned over to the Institute, which gladly agreed to administer the fund and to employ the income therefrom to provide an annual award.

This award shall be known as the Browder J. Thompson Memorial Prize. Its purpose shall be to stimulate research in the field of radio and electronics and to provide incentive for the careful preparation of papers describing such research. The award shall be made annually to the author or joint authors under thirty years of age at date of submission of original manuscript (in case of joint authorship, all authors shall be under thirty years of age at date of submission of original manuscript) for that paper of sound merit recently published in the Technical Publications of The Institute of Radio Engineers which, in the opinion of the Awards Committee of the Institute, constitutes the best combination of technical contribution to the field of radio and electronics and presentation of the subject. The Memorial Fund, accumulated from contributions of friends of the late B. J. Thompson, shall be turned over to the I.R.E. and administered by the Investments Committee of the Institute. The annual prize in any particular year shall consist of the approximate amount of the annual income received from this Fund. The Investments Committee of the Institute will determine from time to time the amount of the average annual income so as to avoid undue fluctuations from year to year due to variations in rate of income, defaults in interest payments, back-interest payments, etc. In case the Awards Committee finds that, in any one year, there is no author or paper meeting the requirements for that year's Award, the Award for that particular year may be postponed until such time as the Awards Committee determines upon a suitable recipient, or the income may be used for increasing the amount of the Award over a suitable period of years.

The foregoing specifications are intended to provide for the normal administration of the award. If there arise unusual conditions or emergencies such as those which would involve suspension of publication, delayed appreciation of the value of a particular contribution, or secrecy restrictions which make it impossible for an author to submit manuscript in a normal manner, the Awards Committee may, at their discretion, depart from a strict intrepretation of the conditions "recent" and "under thirty years of age at date of submission of original manuscript."

Furthermore, in the event that the specific provisions of this gift shall, in the opinion of the Board of Directors of the Institute, have become inapplicable to meet changed conditions of the future, the Board of Directors of the Institute may modify the provisions of the Award in such manner as to best carry out the spirit intended by those who contributed to the Fund.

Signed

F. B. Llewellyn

President, Institute of Radio Engineers

A Microwave Relay System*

LELAND E. THOMPSON†, SENIOR MEMBER, I.R.E.

Summary—**A method of double-frequency modulation suitable for long-distance transmission of multichannel signals by means of radio-relay stations is described. Propagation, radio-frequency bandwidth, and radio-frequency power are discussed briefly. The signal-to-noise ratio and distortion of the system are shown by theory and experiment. An experimental circuit between Philadelphia and New York is described and the results are given.**

Introduction

THE DEVELOPMENT of microwave power generation and radiation during the war advanced so far that it now seems economically possible to transmit multichannel telephone and telegraph signals over long distances by means of relay stations spaced from 25 to 50 miles apart. Such services require a high degree of reliability. Interruptions due to interference and propagation failures should be entirely absent.

The microwave region from 2000 to 10,000 megacycles is particularly well suited for such transmissions. In this frequency range the received signal over a propagation path only slightly above grazing is near the free-space value.[1] Interference from a station on the same frequency channel at a much greater distance away than the desired station, even under conditions of unusual propagation and without the help of the directivity of the antennas, is considerably reduced just because the distance to the interfering station is greater than that to the desired station. This is a more favorable condition than on lower frequencies where, for example, on 40 to 100 megacycles the received signal at a distance of 25 miles over a propagation path slightly above grazing would be considerably below the free-space value and an interfering signal from a greater distance may be so much nearer the free-space value that, with the same transmitted power, it is actually stronger than the desired signal under unusual propagation conditions.

This more favorable propagation characteristic of microwave frequencies together with sharply directional antennas provides a much greater opportunity to use the same frequency channel over and over again than was ever possible on lower frequencies.

It is well known that frequency modulation with a large deviation ratio provides a gain in signal-to-noise ratio at the expense of increased bandwidth.[2,3] In other words, for a given signal-to-noise ratio, less radio-frequency power is required than in an amplitude-modulation system, or in a frequency-modulation system with a low deviation ratio. In addition to the economy of a low-power system, there is the advantage of the greater possibility of using the same frequency channel over and over even in the same local geographical area, because of the interference-suppression effect of frequency modulation.

For example, assume that in a terminal station in a metropolitan area, which is the terminating point of several microwave relay circuits, each relay circuit is a two-way circuit and that each radiates from the terminal station in a different direction. All the receivers at the terminal station may use one common frequency channel and all the transmitters may use a second one. Interference between the different circuits would be eliminated by the directivity of the antennas and by the interference suppression of frequency modulation. With an amplitude-modulation system, or any system which would depend on the antenna directivity alone for interference elimination, such common use of one frequency channel would not be practical, at least not with the antenna designs in use at the present time. In this case, although the frequency band required for each of the circuits would be smaller, each circuit would require a separate frequency channel. Probably a total frequency spectrum greater than that used when all the circuits can operate on a common frequency channel would be required.

It is evident that bandwidth alone is not a measure of the "space" required by a particular system. The type of modulation and the amount of radio-frequency power used are of great importance in efficient use of the spectrum.

The Double-Frequency-Modulation System

The ability to modulate, relay, and demodulate a number of simultaneous signal channels without objectionable noise or cross talk is as important as the ability to generate and to radiate radio-frequency power. This system of modulation makes use of frequency separation of the various signal channels. The modulation range is from 30 cycles to 150 kilocycles. Any of the systems of channeling used on long wire-line telephone[4] and telegraph[5] systems may be used.

The intelligence or signaling band of frequencies is used to frequency-modulate or phase-modulate a subcarrier to 1.0 megacycle. The modulated subcarrier then frequency-modulates the radio-frequency carrier.

* Decimal classification: R480×R310. Original manuscript received by the Institute, May 9, 1946; revised manuscript received, July 26, 1946.

† RCA Victor Division, Radio Corporation of America, Camden, New Jersey.

[1] C. W. Hansell, "Radio-relay-systems development by the Radio Corporation of America," Proc. I.R.E., vol. 33, pp. 156–168; March, 1945.

[2] Edwin H. Armstrong, "A method of reducing disturbances in radio signaling by a system of frequency modulation," Proc. I.R.E., vol. 24, pp. 689–740; May, 1936.

[3] Murray G. Crosby, "Frequency modulation noise characteristics," Proc. I.R.E., vol. 25, pp. 472–514; April, 1937.

[4] B. W. Kendal and H. A. Affel, "A twelve-channel carrier telephone system for open-wire lines," *Bell Sys. Tech. Jour.*, vol. 18, pp. 119–142; January, 1939.

[5] F. B. Bramhall and J. E. Boughtwood, "Frequency-modulated carrier telegraph system," *Trans. A.I.E.E.* (Elec. Eng., January, 1900), vol. 61, pp. 36–39; January, 1942.

A pre-emphasis network is used to increase the deviation of the subcarrier to approximate linearity with increasing modulating frequency between 10 and 150 kilocycles, so that the signal-to-noise ratio on all of the channels will be the same. Below 10 kilocycles, pre-emphasis does not take place. Above 10 kilocycles the modulation is more correctly called phase modulation, since the deviation increases with modulating frequency.

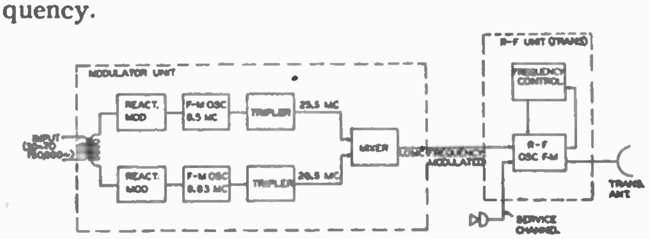


Fig. 1—Block diagram of the terminal transmitter.

The method of generating and modulating the subcarrier is shown in Fig. 1. Two oscillators are frequency-modulated by two reactance-modulator tubes. Each oscillator output is coupled to a tripler stage, and the outputs of the two tripler stages couple to a mixer stage. The plate circuit of the mixer stage is tuned to the frequency difference between the frequencies of the two input voltages. The input modulating voltage is fed in push-pull fashion to the grids of the reactance modulators. The output frequency swing of the 1.0-megacycle subcarrier is, because of the action of the tripler stages, three times the sum of the swings produced by the two modulators. The maximum frequency swing of the subcarrier is plus and minus 400 kilocycles.

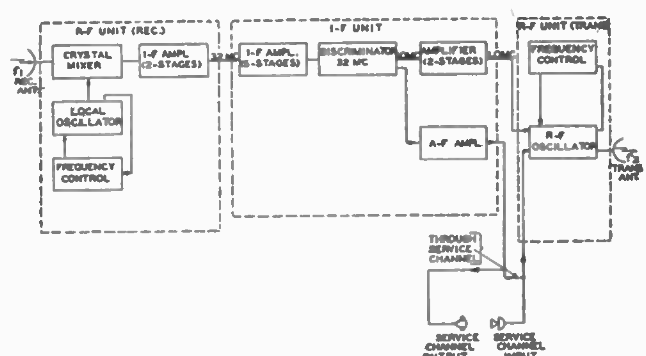


Fig. 2—Block diagram of a relay receiver and transmitter.

The microwave unit of the transmitter uses a reflex oscillator.[6] A relatively low-power oscillator tube has been used in the experimental system. The modulated subcarrier is coupled to the repeller electrode circuit of the oscillator tube to produce the frequency modulation of the microwave carrier. The frequency swing is plus and minus 2.0 megacycles.

The frequency control consists of a high-Q cavity circuit which stabilizes the frequency of the oscillator by means of an automatic-frequency-control circuit.

At a relay station the signal is received by a superheterodyne receiver with an intermediate frequency of 32 megacycles and a bandwidth of 4 megacycles. Fig. 2 is a block diagram of a relay receiver and transmitter. The last limiter in the intermediate-frequency amplifier connects to a 32-megacycle discriminator which has a frequency range from audio frequencies up to about 1.5 megacycles. The frequency-modulated subcarrier output of the discriminator is amplified by a two-stage amplifier and limiter with interstage-coupling circuits broadly tuned to 1.0 megacycle. The output of this amplifier is coupled to the repeller-electrode circuit of the relay-transmitter oscillator and thus frequency-modulates the relay transmitter.

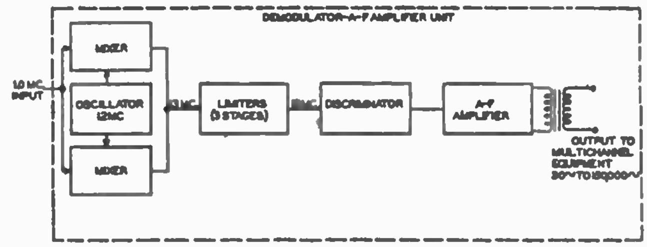


Fig. 3—Block diagram of the demodulator used at a terminal station.

At a terminal receiving station, the output circuit of the subcarrier amplifier connects to a second demodulator. The circuits of the demodulator are shown in block-diagram form in Fig. 3. By the use of an oscillator and a balanced mixer circuit, the 1.0 megacycle subcarrier is changed to a frequency of 13.0 megacycles. A three-stage limiter is used before the final discriminator, which operates at the center frequency of 13.0 megacycles.

The modulation characteristic of the transmitter oscillator as well as of the 32-megacycle discriminator need not be linear because the modulation applied to the oscillator and the output voltage of the discriminator are the subcarrier wave, and this is a frequency-modulated wave and not subject to any harmful effects by passing through nonlinear circuits.

A comparatively simple system of relaying is thus provided, since the relay-transmitter radio-frequency circuits contain a single tube, the reflex oscillator.

For successful operation and maintenance of a relay system consisting of a number of relay stations that are normally unattended, a means of communication from a terminal station to any relay station, and also between any two relay stations, is very desirable. A means of locating failures in the system from a terminal station is almost a necessity for prompt repair and servicing. This service channel is provided by frequency-modulating the transmitter oscillator directly with audio frequencies in addition to the subcarrier modulation.

At each relay station, this audio frequency is separated from the subcarrier at the 32-megacycle discriminator and then applied again to the outgoing transmitter oscillator. A microphone and headphone are connected in this circuit at each relay station. This service channel also provides the necessary circuit for the signals which locate failure.

[6] J. R. Pierce, "Reflex oscillators," Proc. I.R.E., vol. 33, pp. 112–118; February, 1945.

Nonlinearity in the modulation characteristics of the oscillator and the 32-megacycle discriminator cause distortion in this channel, but a relatively high value of distortion here is not objectionable. Because of the large frequency separation, cross modulation with the subcarrier channels does not result.

The radio-frequency circuit components of the experimental equipment are illustrated in Fig. 4. The antenna is shown at the top. The transmitter oscillator appears at the lower left. These components were designed for a frequency range of 3000 to 3300 megacycles. The concentric-line output of the oscillator tube is capacitance-coupled to a section of concentric line containing two sliding insulator sections, each a quarter-wavelength long. By adjusting the position of the two insulators, the oscillator tube is matched to the transmission line and antenna. At the lower right in Fig. 4 is shown the receiver oscillator and mixer unit. The output of the oscillator tube couples to a quarter-wave concentric-line resonant circuit by means of a capacitance probe. A small loop couples the antenna to the resonant circuit across which the crystal rectifier is connected. The output terminal shown at the top of the unit connects to the intermediate-frequency amplifier.

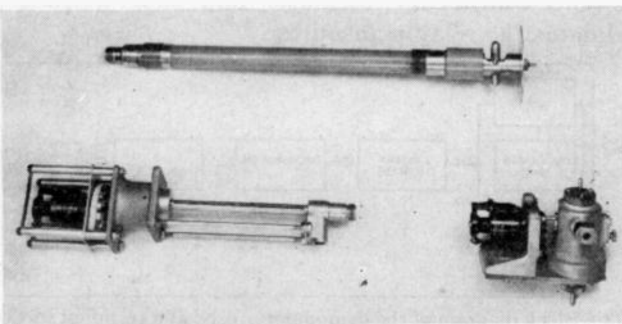


Fig. 4—Experimental radio-frequency circuit components.

Signal-to-Noise Ratio

The received-carrier-to-noise ratio depends on a number of factors. First, the propagation path should be clear of any obstructions such as hills, trees, etc. The other factors determining the received-carrier-to-noise ratio are transmitter power, diameter of the antenna reflector, wavelength, distance, receiver bandwidth, and receiver noise factor. The value of the carrier-to-noise ratio may be calculated for these latter factors from the formulas given by Hansell.[1]

With either frequency modulation or amplitude modulation the signal-to-noise ratio at the output of the receiver is not the same value as the carrier-to-noise ratio before the last detector; this is the case if the bandwidth of the intermediate-frequency-amplifier circuits is greater than twice the frequency-response range of the audio circuits. The signal-to-noise ratio is improved by a factor that is determined by the bandwidth reduction. In the case of amplitude modulation the equation for signal-to-noise ratio (S/N) is

$$\left(\frac{S}{N}\right)_{AM} = M\sqrt{\frac{(BW)}{2f_a}}\,\frac{C}{N} \qquad (1)$$

where (BW) is the intermediate-frequency bandwidth, f_a is the audio-frequency bandwidth, M is the modulation factor, C is the carrier voltage, and N the noise voltage ahead of the last detector. When the frequency-modulation improvement factor[2] is applied to (1), the equation for the signal-to-noise ratio with frequency modulation is

$$\left(\frac{S}{N}\right)_{FM} = \sqrt{3}\,D\sqrt{\frac{(BW)}{2f_a}}\,\frac{C}{N} \qquad (2)$$

where D is the ratio between the frequency deviation and the highest modulating frequency.

The signal-to-noise ratio equations for the double-frequency-modulation system are derived in the appendix. The equation for the first or audio-frequency channel is

$$\left(\frac{S}{N}\right)_{DFM} = \frac{\sqrt{3}}{\sqrt{2}}\,D_1D_2\sqrt{\frac{(BW)}{2f_a}}\,\frac{C}{N} \qquad (3)$$

where D_1 is the ratio between the frequency swing of the carrier and the subcarrier frequency, and D_2 is the ratio between the frequency deviation of the subcarrier by the audio frequencies and the highest audio frequency of this channel.

The signal-to-noise ratio equation for the carrier channels above the audio channel, where the subcarrier is phase modulated, is

$$\left(\frac{S}{N}\right)_{FPM} = \frac{1}{\sqrt{2}}\,D_1D_3\sqrt{\frac{(BW)}{2f_a}}\,\frac{C}{N} \qquad (4)$$

where D_3 is the ratio between the frequency deviation of the subcarrier by any one channel and the mid-frequency of this channel and f_a is the band-width of this signal channel. It is assumed in all of the above cases that the carrier-to-noise ratio is above the threshold value and that the total frequency swing of the subcarrier by all of the signal channels does not exceed the linear range of the subcarrier modulator and demodulator.

Distortion

Cross talk in a multichannel modulation system depends on the distortion in the system. The sources of distortion in frequency modulation are the amplitude nonlinearity of the modulator and the demodulator as well as the nonlinear phase characteristics of the circuits between the modulator and the demodulator.

Measurements of the distortion in this system with the modulator connected directly to the demodulator are shown by the curve in Fig. 5.

The second source of distortion, nonlinear phase characteristics of tuned circuits, is an important factor in a relay system composed of a large number of relay stations. Both Roder[7] and Jaffe[8] show that this distortion

[7] H. Roder, "Effects of tuned circuits upon a frequency-modulated signal," Proc. I.R.E., vol. 25, pp. 1617–1647; December, 1937.

[8] David Lawrence Jaffe, "A theoretical and experimental investigation of tuned-circuit distortion in frequency-modulation systems," Proc. I.R.E., vol. 33, pp. 318–333; May, 1945.

is high, even in one circuit, when the frequency swing is near or greater than the bandwidth of the tuned circuit and when the modulating frequency is a high audio frequency. The distortion reduces rapidly with a reduction of frequency swing. However, distortion is still a serious factor when a large number of tuned circuits are used, as in a long relay system.

The nonlinear phase characteristic of the receiver intermediate-frequency-amplifier circuits will first be considered. The action of these circuits on the signal frequencies is of the greatest importance because of the relatively large number of such circuits in the system. It was determined in the experimental system that tuning all these circuits to one side or the other of resonance did not produce a measurable change in the over-all distortion. Also it was found that the over-all distortion did not change with the percentage modulation (or frequency swing) of the carrier. It was concluded that the intermediate-frequency-amplifier circuits are not an important source of distortion in this double-frequency-modulation system.

The subcarrier amplifier and limiter tuned circuits are a source of distortion. By making these circuits sufficiently broad in frequency response, a satisfactory phase characteristic can be obtained such that a large number of relay stations may be used. An advantage of such low-Q circuits is that they are relatively stable under normal changes of temperature and humidity, and thus make practical the use of phase-corrective networks should they be necessary in an extremely long relay system.

Comparison with Single Frequency Modulation

It is reasonable to compare the signal-to-noise ratios of this system with a single-frequency-modulation system on the basis of equal transmission bandwidths and equal transmitted powers. Both systems can be designed for any given bandwidth and power, within practical limits.

Comparing (2) for frequency modulation with (3) for double frequency modulation, assuming equal bandwidths, power, and modulating frequencies,

$$\frac{\left(\frac{S}{N}\right)_{FM}}{\left(\frac{S}{N}\right)_{DFM}} = \frac{\sqrt{2}\,D}{D_1 D_2} \qquad (5)$$

gives the ratio of the signal-to-noise ratios of the two systems. Assuming values for D_1 and D_2 according to the system described, D_1 is equal to 2 and the ratio of D to D_2 is 5, since the maximum frequency swing of the subcarrier is 400 kilocycles and the maximum frequency swing for a frequency-modulation system with a bandwidth of 4.0 megacycles would be 2.0 megacycles. The single-frequency-modulation system has a greater signal-to-noise ratio by a factor of 3.5, or about 11 decibels.

In the case of the single-frequency-modulation system, the modulation on the carrier passing through the intermediate-frequency circuits of the receivers is the signaling frequency. To maintain a sufficiently low value of cross talk due to nonlinear phase distortion, it is probable that the full peak-to-peak deviation equal to the bandwidth could not be used, and the signal-to-noise ratio would therefore be reduced. Another factor to be considered in the single-frequency-modulation system (assuming relaying is accomplished without demodulation at the relay stations) is the frequency instability of the transmitters. The instability adds up along the system. That is, the frequency of the received carrier at the final receiver in the chain depends not only on the last transmitter, but on all of the transmitters and all of the receiver oscillators in the chain. A suitable allowance for frequency drift would reduce the permissible peak frequency swing.

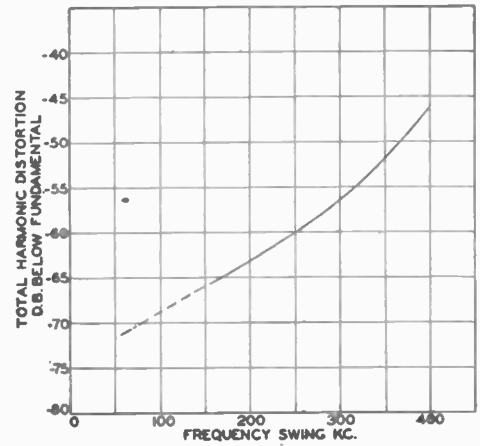


Fig. 5—Over-all distortion of the modulator and demodulator units.

While these results have indicated reasons for choice of the double-frequency-modulation system, it is difficult to make an exact comparison at the present time. The normal progress of development will make a more conclusive comparison possible in the future. However, the experimental results described below tend to confirm the correctness of these conclusions.

Experimental Results

An experimental two-way circuit constructed between Philadelphia and New York City was placed in operation in April, 1945. The location of this circuit is shown on the map of Fig. 6. Two relay stations are used, one near Bordertown, New Jersey, and the other near New Brunswick, New Jersey, at a site named Ten Mile Run.

The photograph of Fig. 7 shows the tower with antenna reflectors at the Bordentown relay station. The Ten Mile Run station is similar. The towers are 100 feet in height. The experimental equipment was placed in the enclosure at the top of each tower. The design of later models permits the installation of most of the equipment at ground level, with the transmitter oscillator, receiver oscillator, mixer, and first amplifier located near the antennas.

The facilities for the installation of the terminal stations at both Philadelphia and New York were made available by the Western Union Telegraph Company, the Engineering Department of which organization co-operated in the field tests of the circuit.

The frequencies used in the experimental tests are near 3300 megacycles. Two frequency channels are

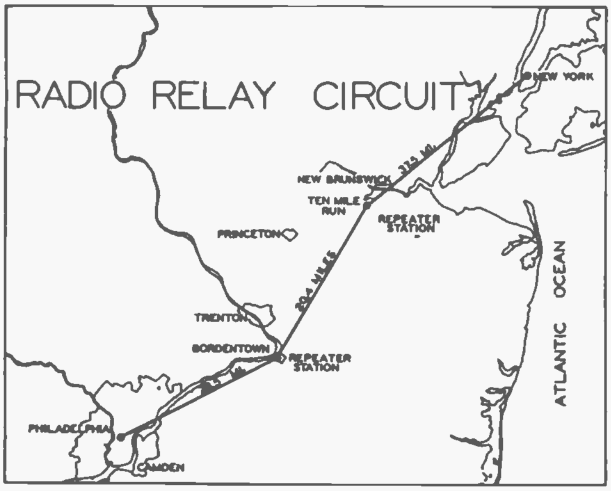


Fig. 6—Location of stations in the experimental circuit.

used for the complete two-way circuit. At each relay station the transmitters in both directions are on the same channel frequency, and the receivers in both directions operate on the other channel frequency.

The transmitter power is approximately 0.1 watt. The antenna parabolic reflectors are 4 feet in diameter. This dimension gives an antenna gain of about 30 decibels and an angular beam width of about 5.5 degrees at the half-power points. The antennas are dipoles fed by concentric transmission lines.

The propagation path between Philadelphia and Bordentown is sufficiently clear above hilltops to allow a geometrically unobstructed path above trees of normal height. The distance is 26.5 miles. The path of the link between Bordentown and Ten Mile Run is well above trees and other obstructions. The distance of this link is 20 miles. The propagation path between Ten Mile Run and New York is not sufficiently clear of the terrain to allow for trees and buildings near the center of the path. The distance is 37.5 miles.

The received-carrier-to-noise ratio was measured over each link of the circuit under normal weather conditions when the received signals were constant. The value of this ratio measured on the Ten Mile Run to New York link was 20. Between Ten Mile Run and Bordentown the ratio was 90, and between Bordentown and Philadelphia the ratio was 68.

To obtain an experimental confirmation of the signal-to-noise ratio of (3), a measurement was made under the following conditions. The subcarrier circuit on the New York receiver was connected directly to the transmitter to form a relay station, so that a one-way loop circuit of 168 miles in length was obtained with the transmitting and receiving ends of the circuit in Philadelphia. Measurements were made at audio frequencies with a filter on the receiver output with a noise band of 15 kilocycles. A modulating frequency of 1000 cycles was used with a swing of 60 kilocycles on the subcarrier.

The signal-to-noise root-mean-square voltage ratio measured about 1000, or 60 decibels. From (3) the calculated value is 67 decibels, with the carrier-to-noise ratio of 20 obtained on the lowest signal link in the circuit. There were two such links of about equal strength and therefore 3 decibels should be subtracted from this calculated figure, giving a value of 64 decibels. The noise contributions of the links having the stronger received signals would be small by comparison and were neglected. Other tests made over a single link checked the theoretical value to about the same degree.

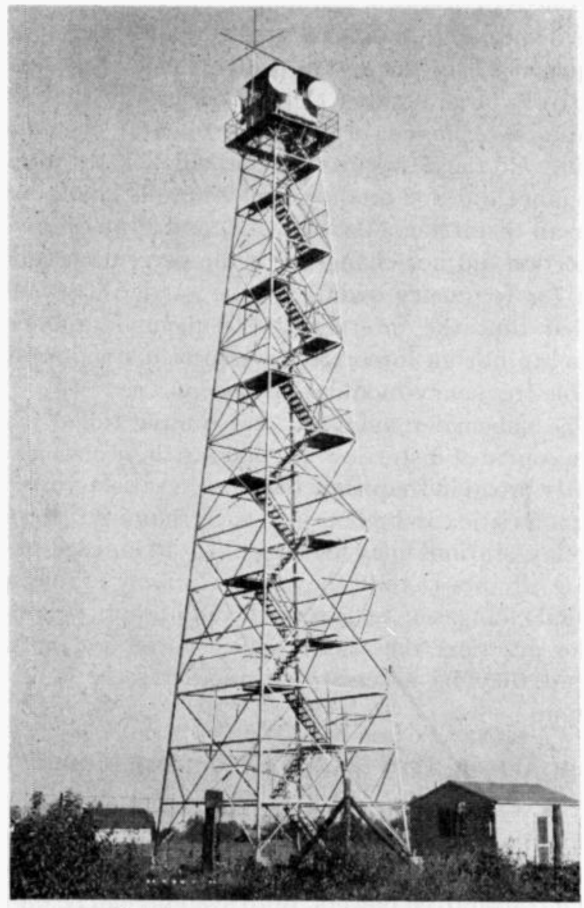


Fig. 7—Relay station near Bordentown, New Jersey.

The distortion over the circuit, measured at a modulation frequency of 200 cycles and a frequency swing of 240 kilocycles on the subcarrier, was about 0.1 per cent, or 60 decibels below the audio signal. This is about the same value as was measured with the modulator unit connected directly to the demodulator and not going through the radio circuit, as is shown in the data of Fig. 5.

The distortion increased with modulating frequency, and at 5000 cycles and a frequency swing of 240 kilocycles, the distortion was 0.7 per cent. This measurement showed the effect of the nonlinear phase characteristic of the subcarrier circuits. Although the frequency swing of 240 kilocycles is very much more than would be used normally with a modulation component at 5000 cycles, the measurement indicated that such distortion can be serious at higher modulation frequencies.

In co-operation with the Engineering Department of the Western Union Telegraph Company, practical tests were made with the use of two carrier telephone channels, about 50 teleprinter channels, a slow-speed tape-facsimile channel, and an audio channel with a fidelity of 30 cycles to 10,000 cycles. This combined modulation extended to a frequency of about 50 kilocycles. Listening tests showed cross talk and noise to be at an acceptably low level. The operation of the teleprinter channels was satisfactory, with no errors noted during the period of the tests on the single printer that was used at the radio terminal.

Propagation records were made over this circuit for about nine months. Generally the results show quite satisfactory performance with the power of 0.1 watt. It is proposed to conduct further tests at greater distances. These tests may indicate that, with sufficient propagation path clearance, distances of 50 to 60 miles may be practical with this low value of power.

The noise level of the circuit was apparently determined entirely by receiver noise. Both terminal receivers are in locations where the noise level caused by electrical machinery is very high at the receiver intermediate frequency of 32 megacycles. Proper grounding and shielding of the intermediate-frequency circuits was necessary to prevent noise from being introduced directly into the intermediate-frequency amplifier.

Conclusion

From both a theoretical and a practical viewpoint, the system of radio relaying described is sufficiently promising for multichannel voice and telegraph communication to warrant further development and an extension of the test circuit. Such work is now in progress.

Acknowledgment

The author wishes to acknowledge the help of a large number of co-workers in the course of this work. The support and guidance of John B. Coleman and Donald S. Bond is particularly appreciated. The help of F. C. Collings and his group in the early development stage and of G. Gerlach and his group in the later field-test stage contributed materially to the development. The early experience in the microwave field of N. I. Korman and C. G. Sontheimer was of particular value in the course of this work.

The support and interest in the development shown by F. E. d'Humy and H. P. Corwith of the Western Union Telegraph Company is very much appreciated. In particular, the assistance of F. B. Bramhall, J. Z. Miller, and W. B. Sullinger, J. E. Boughtwood, and M. Cantor of the Engineering Department of that company contributed materially to the success of the tests.

Appendix

Consider the signal and noise at the first frequency-modulation detector in the receiver. If the frequency-modulation peak-to-peak swing of the carrier by the subcarrier wave before detection is equal to the intermediate-frequency bandwidth, the amplitude of the subcarrier after detection is the same as the amplitude of the carrier ahead of the detector, if the efficiency of the frequency-modulation detector is 100 per cent. Crosby[3] has shown that, if sufficient limiting is used, the efficiency of the detector does not change the output signal-to-noise ratio, both the signal and the noise being reduced with a detector of low efficiency. It is then permissible to assume an efficiency of 100 per cent.

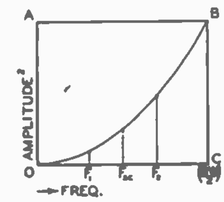


Fig. 8—Amplitude-modulation and frequency-modulation receiver noise-power spectra.

In Fig. 8, the rectangle $OABC$ represents the average noise-power output of an amplitude-modulation detector, and the area OBC represents the average noise-power output of a frequency-modulation detector. Crosby[3] has shown that the ratio of these two values of power is 3 to 1. This result is found by a comparison of the squared ordinate areas of the two noise-voltage spectra. Similarly, the area OBC compared to the area under the curve between F_1 and F_2, is as the squared ordinate areas, and the power ratio is

$$\frac{\int_0^{(BW/2)} F^2 dF}{\int_{F_1}^{F_2} F^2 dF} = \frac{\left(\frac{BW}{2}\right)^3}{F_2^3 - F_1^3}. \tag{6}$$

The subcarrier-to-noise root-mean-square voltage ratio following the first frequency-modulation detector, considering only noise between F_1 and F_2, is then

$$\frac{C_{sc}}{N} = \sqrt{3}\, M \sqrt{\frac{\left(\frac{BW}{2}\right)^3}{F_2^3 - F_1^3}}\, \frac{C}{N} \tag{7}$$

where C/N is the carrier-to-noise ratio in the intermediate-frequency amplifier ahead of the detector and M is the amount of frequency swing compared to the bandwidth and is equal to 1 at a frequency swing equal to half the bandwidth.

Following the second frequency-modulation detector, the signal-to-noise ratio improves over that ahead of the detector by the well-known factor $\sqrt{2}$ times the deviation ratio, and also because of a bandwidth reduction produced by the channel audio-frequency filter following the detector. The signal-to-noise ratio following this filter is

$$\frac{S}{N} = \sqrt{3}\, D_2 \sqrt{\frac{F_2 - F_1}{2f_a}}\, \frac{C_{sc}}{N} \tag{8}$$

where f_a is the audio band of the filter.

Substituting (7) and (8)

$$\frac{S}{N} = 3MD_2\sqrt{\frac{F_2 - F_1}{2f_a}}\sqrt{\frac{\left(\frac{BW}{2}\right)^3}{F_2^3 - F_1^3}}\frac{C}{N} \quad (9)$$

$$= \frac{3}{\sqrt{2}}D_2\frac{M\left(\frac{BW}{2}\right)}{\sqrt{F_2^2 + F_1F_2 + F_1^2}}\sqrt{\frac{(BW)}{2f_a}}\frac{C}{N}. \quad (10)$$

Equation (10) gives the signal-to-noise ratio of the first audio-frequency channel with a filter passing frequencies up to f_a. If F_1 and F_2 approach F_{sc}, the frequency of the subcarrier,

$$\frac{M\left(\frac{BW}{2}\right)}{\sqrt{F_2^2 + F_1F_2 + F_1^2}} = \frac{M\left(\frac{BW}{2}\right)}{\sqrt{3}F_{sc}} = \frac{1}{\sqrt{3}}D_1 \quad (11)$$

where D_1 is the ratio of the deviation of the carrier by the subcarrier. Equation (10) then becomes

$$\left(\frac{S}{N}\right)_{DFM} = \frac{\sqrt{3}}{\sqrt{2}}D_1D_2\sqrt{\frac{(BW)}{2f_a}}\frac{C}{N}. \quad (3)$$

In the system described, F_1 is equal to 600 kilocycles and F_2 is equal to 1400 kilocycles, and the error in using (3) instead of (10) is

$$\frac{\sqrt{1.4^2 + 0.6 \times 1.4 + 0.6^2}}{\sqrt{3} \times 1} = \frac{\sqrt{3.16}}{\sqrt{3}} = 1.03. \quad (12)$$

It is not necessary to use a band-pass filter in the subcarrier circuits to eliminate noise components below F_1 and above F_2, as these components produce noise in the receiver output circuits beyond the modulation range and are eliminated by the channel filters.

Similarly, the signal-to-noise ratio in any band of modulation frequencies between F_3 and F_4 at the output of the second frequency-modulation detector is

$$\frac{S}{N} = \sqrt{3}M_1\sqrt{\frac{\left(\frac{F_2 - F_1}{2}\right)^3}{F_4^3 - F_3^3}}\frac{C_{sc}}{N} \quad (13)$$

$$= \sqrt{3}M_1\frac{\left(\frac{F_2 - F_1}{2}\right)}{\sqrt{F_4^2 + F_3F_4 + F_3^2}}\sqrt{\frac{F_2 - F_1}{2(F_4 - F_3)}}\frac{C_{sc}}{N} \quad (14)$$

where M_1 is the amount of frequency swing of the subcarrier compared to the bandwidth of the subcarrier circuits and is equal to 1 at a frequency swing equal to $(F_2 - F_1)/2$.

If F_3 and F_4 approach the mid-channel frequency, F_m,

$$M_1\frac{\left(\frac{F_2 - F_1}{2}\right)}{\sqrt{F_4^2 + F_3F_4 + F_3^2}} = \frac{M_1\left(\frac{F_2 - F_1}{2}\right)}{\sqrt{3}F_m} = \frac{1}{\sqrt{3}}D_3 \quad (15)$$

where D_3 is the ratio between the deviation of the subcarrier by the frequencies between F_3 and F_4 and the mid-channel frequency, F_m. Equation (14) then becomes

$$\frac{S}{N} = D_3\sqrt{\frac{F_2 - F_1}{2(F_4 - F_3)}}\frac{C_{sc}}{N} \quad (16)$$

$$= D_3\sqrt{\frac{F_2 - F_1}{2f_a}}\frac{C_{sc}}{N} \quad (17)$$

where f_a is the bandwidth of any channel above the audio channel. The error introduced by the use of (15) is very small. For example, the error in calculating a channel of 4 kilocycles between 18 and 22 kilocycles would be 0.16 per cent.

Substituting equation (7) in (17) in the same manner as it was substituted in (8), it is found that

$$\left(\frac{S}{N}\right)_{FPM} = \frac{1}{\sqrt{2}}D_1D_3\sqrt{\frac{(BW)}{2f_a}}\frac{C}{N}. \quad (4)$$

Noise-Figure Reduction in Mixer Stages*

M. J. O. STRUTT†, SENIOR MEMBER, I.R.E.

Summary—**This paper presents some aspects of random noise reduction in mixer stages connected with the application of proper circuit design and feedback, taking into account the intercorrelation of noise components. The noise figure of diode mixer stages is derived from their basic operational data. Conditions conducive to optimal gain are shown to be coincident with those of minimum noise, the diode's contribution approaching zero in the most favorable case. The noise of triode and multigrid mixer stages is shown to be reducible to the value for a comparable triode amplifier stage by the application of proper feedback. In some cases this reduction amounts to 15 decibels or more. Oscillator noise and push-pull stages are discussed.**

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I. Introduction

IT IS GENERALLY recognized that noise in mixer stages is in many cases relatively higher than in comparable amplifier stages at proper operation.[1–3] This often prohibits the use of such mixer stages at the entrance of receivers aiming at a particularly high sensitivity. On the other hand, this use is often desirable from the point of view of receiver design, as it promotes

[1] E. W. Herold, "Superheterodyne converter system considerations in television receivers," *RCA Rev.*, vol. 4, pp. 324–337; 1940.

[2] E. W. Herold, "The operation of frequency converters and mixers for superheterodyne reception," Proc. I.R.E., vol. 30, pp. 84–103; February, 1942.

[3] M. J. O. Strutt, "Mixing valves," *Wireless Eng.*, vol. 12, pp. 59–64; 1935.

simplicity. A reduction of noise in mixer stages seems, therefore, to be of particular interest.

Several definitions of noise figures have been proposed in recent years[4-12] aiming at the provision of an adequate measure of the noise of reception stages. We shall make use here of a figure proposed recently by H. T. Friis[6,10] and bearing a close relation to one proposed and used earlier by K. Fraenz,[4,5] and by W. Kleen.[8] It starts from the definition of the noise ratio at the output of a stage as the ratio of available noise power to available signal power. The noise figure F is then defined as the ratio of the noise ratio of the stage's output terminals to the noise ratio at the output terminals of the preceding stage.

A different relative measure, useful at radio frequencies, is the equivalent noise resistance of a stage.[7,13,14] This is a resistance which, at room temperature, causes a noise voltage at its terminals, equal to the equivalent noise voltage at the stage's input terminals. The latter creates an available noise power at the output terminals of the now noise-free stage equal to that due to the real stage itself with its input terminals short-circuited. We shall refer to this noise resistance in section IV.

II. Diode Mixer Stages at Radio Frequencies

Referring to recent publications on diode mixer stages[11,15-17] we shall describe their operation, disregarding image and other spurious responses, by a set of four-terminal equations

$$\begin{aligned} I_{in} &= S_0 V_{in} - S_1 V_{out}, \\ I_{out} &= S_1 V_{in} - S_0 V_{out}. \end{aligned} \tag{1}$$

In (1), I_{in} represents the input current of angular frequency ω_{in}, and I_{out} the complex output current of angular frequency ω_{out} in the usual complex notation, while the local oscillator's angular frequency is, $\pm\omega_{os} = \omega_{in} - \omega_{out}$. Similarly, V_{in} and V_{out} are the complex input and output voltages of angular frequencies ω_{in}, and ω_{out}, respectively. If $\omega_{os} = \omega_{in} + \omega_{out}$, instead of (1) we obtain

$$\begin{aligned} I_{in} &= S_0 V_{in} - S_1 V_{out}^*, \\ I_{out}^* &= S_1 V_{in} - S_0 V_{out}^*, \end{aligned} \tag{2}$$

the asterisks indicating conjugate complex values. The signs in (1) and (2) are connected with the positive directions assumed for the currents and voltages in Fig. 1.

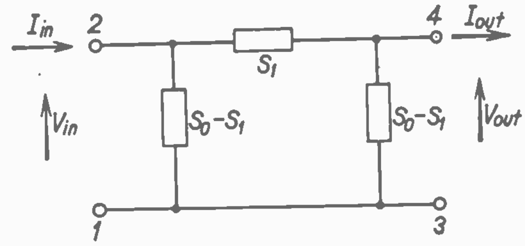

Fig. 1—Equivalent passive four-terminal network of a diode mixer stage at radio frequencies, its operation being described by equations (1) or (2).

At radio frequencies, the effects caused by electronic transit times being completely disregarded, S_0 and S_1 are *real* quantities related in a simple way to the diode's properties under normal operating conditions. Denoting the oscillator voltage acting in series with the diode by $V_{os} \cos \omega_{os} t$, the diode's admittance S is

$$S = S_0 + 2S_1 \cos \omega_{os} t + 2S_2 \cos 2\omega_{os} t + \cdots. \tag{3}$$

One predominant assumption is that the voltages V_{in} and V_{out} are small in amplitude with respect to the amplitude V_{os}. This basic expression (3) was introduced by the author in 1936.[18] We shall use the convention $\omega_{os} = \omega_{in} - \omega_{out}$ and $\omega_{in} > \omega_{out}$ corresponding to (1) for our further discussion.

The gain figure g of a diode mixer stage, being the ratio of available output power corresponding to ω_{out} to the available input power corresponding to ω_{in}, may readily be obtained from (1) as follows:

$$g = \frac{S_1^2}{|S_0 Z_{in} + 1| \left| S_0^2 - S_1^2 + \dfrac{S_0}{Z_{in}} \right|}, \tag{4}$$

Z_{in} denoting the internal impedance of the signal source connected to the diode stage's input terminals, which is appreciable only in the vicinity of ω_{in}. The optimum gain is unity and this figure corresponds to the case $|S_0 Z_{in}| \gg 1$ and $S_0 = S_1$. The latter condition obtains approximately if the diode is operated in class C.

The diode's spontaneous fluctuations may be ascribed to a constant-current generator of infinite internal impedance acting in parallel to the diode's terminals. The mean-square current $\overline{I_f^2}$ of this generator is

$$\overline{I_f^2} = 4kT_c \alpha S \Delta f = 4kT_c Y \Delta f, \tag{5}$$

[4] K. Fraenz, "On the limit of sensitivity at the reception of short waves and its attainability" (in German), *Elek. Nach. Tech.*, vol. 16, pp. 92–96; 1939.

[5] K. Fraenz, "Measurements of receiver sensitivity at ultra-short waves" (in German), *Zeit. Hoch. und Elek.*, vol. 59, pp. 105–112, pp. 143–144; 1942.

[6] H. T. Friis, "Noise figures of radio receivers," Proc. I.R.E., vol. 32, pp. 419–423, 729; July, 1944.

[7] E. W. Herold and L. Mautner, "The signal-to-noise ratio of radio receivers," Proc. I.R.E., vol. 31, pp. 501–510; September, 1943.

[8] W. Kleen, "Gain and sensitivity of ultra-short and decimeter wave reception valves" (in German), *Die Telefunkenröhre*, number 23, pp. 273–296; 1941.

[9] D. K. C. MacDonald, "A note on two definitions of noise figure in radio receivers," *Phil. Mag.*, vol. 35, pp. 386–395; 1944.

[10] D. O. North and H. T. Friis, Discussion on "Noise figures of radio receivers," Proc. I.R.E., vol. 29, pp. 49–50; February, 1945.

[11] H. Rothe and W. Kleen, "Electron Valves as Entrance-Stage Amplifiers" (in German), diode mixers, pp. 231–235, noise figures, pp. 330–336; Alcademischer Verlag, Leipzig, 1944, second edition.

[12] M. J. O. Strutt and A. van der Ziel, "Reduction of the effects of spontaneous fluctuations in amplifiers for meter and decimeter waves" (in German), *Physica* (Hague), vol. 9, pp. 1003–1012; 1942; vol. 10, pp. 823–826; 1943.

[13] M. J. O. Strutt, "Modern Short Wave Reception Technique" (in German), Springer, 1939.

[14] B. J. Thompson, D. O. North, and W. A. Harris, "Fluctuations in space charge limited currents at moderately-high frequencies," *RCA Rev.*, Part I, vol. 4, pp. 269–285; 1940; Part II, vol. 4, pp. 441–472; 1940; Part III, vol. 5, pp. 214–260; 1940; Part IV, vol. 5, pp. 371–388; Part V, vol. 6, pp. 114–124, 505–524; 1941.

[15] E. W. Herold and L. Mautner, "Frequency mixing in diodes," Proc. I.R.E., vol. 31, pp. 575–581; October, 1943.

[16] E. W. Herold, R. R. Bush, and W. R. Ferris, "Conversion loss of diode mixers having image-frequency impedance," Proc. I.R.E., vol. 33, pp. 603–609; September, 1945.

[17] E. C. James and J. E. Houldin, "Diode frequency changers," *Wireless Eng.*, vol. 20, pp. 15–27; 1943.

[18] M. J. O. Strutt, "Diode frequency changers," *Wireless Eng.*, vol. 13, pp. 73–80; 1936.

k being Boltzmann's constant ($1.38\ 10^{-23}$ joule per degree Kelvin), T_c the cathode temperature in degrees Kelvin, α a multiplier equal to 0.5 in the exponential and to 0.64 in most of the space-charge-limited region of operation,[19] S the diode's admittance as given by (3), and Δf the frequency interval under consideration. The abbreviation Y is used for αS. An equation similar to (3) holds for Y:

$$Y = Y_0 + 2Y_1 \cos \omega_{os}t + 2Y_2 \cos 2\omega_{os}t + \cdots. \qquad (6)$$

The fluctuation amplitudes are proportional to

$$\sqrt{Y} = y_0 + 2y_1 \cos \omega_{os}t + 2y_2 \cos 2\omega_{os}t + \cdots. \qquad (7)$$

From (6) and (7) we obtain

$$Y_0 = y_0^2 + 2y_1^2 + 2y_2^2 + 2y_3^2 + \cdots,$$
$$Y_1 = 2y_0y_1 + 2y_1y_2 + 2y_2y_3 + \cdots. \qquad (8)$$

We now consider fluctuation currents, the relatively small frequency intervals Δf of which are centered round $\omega_{out}, \omega_{os}+\omega_{out}, \omega_{os}-\omega_{out}, 2\omega_{os}+\omega_{out}, 2\omega_{os}-\omega_{out}, 3\omega_{os}-\omega_{out}, 3\omega_{os}+\omega_{out}$, etc., previous to the application of local-oscillator voltage to the diode. These fluctuation currents will be termed a ***complete set of fluctuation components.*** Upon the application of oscillator voltage this complete set becomes

$$\begin{aligned} &p\sqrt{Y} \cos (\omega_{out}t + a_0),\\ &p\sqrt{Y} \cos \{(\omega_{os} + \omega_{out})t + a_1\},\\ &p\sqrt{Y} \cos \{(\omega_{os} - \omega_{out})t + b_1\},\\ &p\sqrt{Y} \cos \{(2\omega_{os} + \omega_{out})t + a_2\},\\ &p\sqrt{Y} \cos \{(2\omega_{os} - \omega_{out})t + b_2\}, \text{ etc.,} \end{aligned} \qquad (9)$$

p^2 being an abbreviation for $8kT_cT_c\Delta f$. The phase-angles a_0, a_1, a_2, etc., are random and uncorrelated. These currents (9) may be ascribed to separate uncorrelated constant-current generators of infinite internal impedance acting in parallel to the diode's terminals. It may be useful to observe that an apparently different complete set of fluctuation components is obtained by considering intervals Δf centered round $\omega_{in}, \omega_{os}+\omega_{in}, |\omega_{os}-\omega_{in}|, 2\omega_{os}+\omega_{in}, |2\omega_{os}-\omega_{in}|$, etc. In fact, each of these frequencies may be identified with one particular frequency of the previous set, and hence no real difference exists.

The stage is now set for the evaluation of the noise figure of the diode mixer stage. Its calculation is simplified by short-circuiting the output terminals. The output noise ratio is then obviously equal to the mean-square fluctuation current corresponding to a frequency interval Δf centered around ω_{out}, divided by the signal current squared at ω_{out}, flowing through the said short-circuit. Because of the random character of the fluctuation currents, the diode itself presents an average admittance S_0 to them (as in (3)). As mentioned before, Z_{in} has an appreciable value in the vicinity of ω_{in} and is zero at widely different frequencies. The fluctuation currents in the short-circuit lead connecting the output terminals 3 and 4 may be obtained from Fig. 2. First, we shall deal with the fluctuations due to the diode. Inserting the value (7) of $\sqrt{Y}$ into (9), the first of the components in the latter equations causes a fluctuation current $py_0 \cos(\omega_{out}t+a_0)$ in the output short-circuit lead. Furthermore, it causes a fluctuation voltage

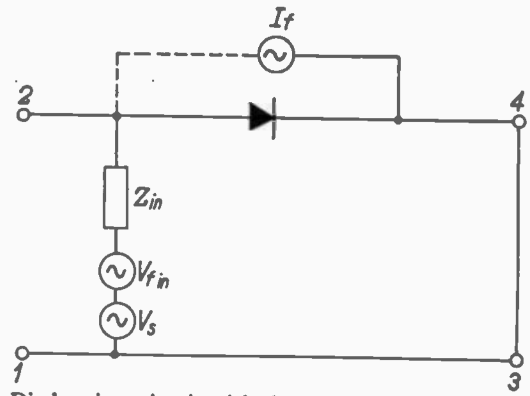

Fig. 2—Diode mixer circuit with short-circuited output terminals 3 and 4. The diode's fluctuations are ascribed to a constant-current generator I_f of infinite internal impedance. The signal and the input noise are ascribed to constant-voltage generators V_s and $V_{f\,in}$ of zero internal impedance in series with the impedance Z_{in} connected to the mixer stage's input terminals.

$$-\frac{py_1}{S_0 + \dfrac{1}{Z_{in}}} \cos (\omega_{in}t + a_0)$$

across the impedance Z_{in}. This voltage in turn causes a current

$$-\frac{py_1S_1}{S_0 + \dfrac{1}{Z_{in}}} \cos (\omega_{out}t + a_0)$$

through the output lead. Both current components mentioned through this lead are completely correlated, as appears from their equal phases a_0. The other component currents of (9) may be dealt with similarly. Thus, the second one results in an output fluctuation current at ω_{out}

$$\left(py_1 - py_0\frac{S_1}{S_0 + \dfrac{1}{Z_{in}}}\right) \cos (\omega_{out}t + a_1)$$

and the third one in a current

$$\left(py_1 - py_2\frac{S_1}{S_0 + \dfrac{1}{Z_{in}}}\right) \cos (\omega_{out}t - b_1), \text{ etc.}$$

The total mean-square diode fluctuation current through the output lead is obtained by squaring the individual currents mentioned, adding the moduli of all the squares, and averaging over one period $2\pi/\omega_{out}$. Assuming Z_{in} to be real: $Z_{in} = R_{in}$, the result is

[19] A. J. Rack, "Effect of space charge and transit time on the shot noise in diodes," *Bell Sys. Tech. Jour.*, vol. 17, pp. 592–619; 1938.

$$\overline{I_{fd}^2}=\frac{p^2}{2}\left[(y_0^2+2y_1^2+2y_2^2+\cdots)\left\{1+\frac{S_1^2}{\left(S_0+\frac{1}{R_{in}}\right)^2}\right\} - 4(y_0y_1+y_1y_2+y_2y_3+\cdots)\frac{S_1}{S_0+\frac{1}{R_{in}}}\right].$$

Making use of (8), this equation yields

$$\overline{I_{fd}^2}=4kT_cT_c\Delta f\left\{Y_0-2\frac{Y_1S_1}{S_0+\frac{1}{R_{in}}}+Y_0\frac{S_1^2}{\left(S_0+\frac{1}{R_{in}}\right)^2}\right\}. \quad (10)$$

If the coefficient α in (5) is approximately constant under operating conditions, we have $Y_0=\alpha S_0$ and $Y_1=\alpha S_1$. Hence, in this case

$$\overline{I_{fd}^2}=4kT_cT_c\alpha\Delta f\left\{S_0-2\frac{S_1^2}{S_0+\frac{1}{R_{in}}}+\frac{S_0S_1^2}{\left(S_0+\frac{1}{R_{in}}\right)^2}\right\}. \quad (11)$$

The fluctuations of the signal source also contribute to the fluctuation current at the output. Let the fluctuations at the input be represented by a constant-voltage generator (see Fig. 2) of voltage V_{fin}, given by

$$\overline{V_{fin}^2}=4kT_{in}R_{in}\Delta f, \quad (12)$$

the frequency interval Δf being centered around ω_{in}. Its resulting fluctuation current through the output lead is I_{fr}:

$$\overline{I_{fr}^2}=\overline{V_{fin}^2}\frac{S_1^2S_0^2}{\left(S_0+\frac{1}{R_{in}}\right)^2}=4kT_{in}\Delta f\frac{S_1^2S_0^2R_{in}}{\left(S_0+\frac{1}{R_{in}}\right)^2}. \quad (13)$$

Adding (10) and (13), the total mean-square fluctuation current through the output lead is obtained, at an interval Δf centered around ω_{out}.

Let the signal at the input be derived from a constant-voltage generator V_s (Fig. 2) of angular frequency ω_{in}. The signal current I of angular frequency ω_{out} through the output lead is

$$I = V_s\frac{S_1S_0}{S_0+\frac{1}{R_{in}}}. \quad (14)$$

In the derivation of this equation we first calculate the voltage corresponding to ω_{in} at the terminals 1 and 2 of Fig. 2. As the circuit between 1 and 2, disconnecting Z_{in}, has the impedance $1/S_0$ at ω_{in}, the said voltage is $V_sS_0/(S_0+1/R_{in})$. By the conversion action of the mixer diode we obtain a current I corresponding to ω_{out} through the lead connecting the terminals 3 and 4 of Fig. 2, given by S_1 multiplied by the above voltage, which results in (14). Hence, the noise ratio at the output is, by (10), (13), and (14),

$$\frac{\overline{I_{fd}^2}+\overline{I_{fr}^2}}{I^2},$$

whereas this ratio at the input is $\overline{V_{fin}^2}/V_s^2$. The noise figure F_m of the mixer stage is the ratio of these ratios:

$$F_m = 1+\frac{T_c}{T_{in}}\frac{\alpha_0}{S_0R_{in}}\left\{\frac{\left(S_0+\frac{1}{R_{in}}\right)^2}{S_1^2} - 2\frac{Y_1\left(S_0+\frac{1}{R_{in}}\right)}{Y_0S_1}+1\right\}, \quad (15)$$

α_0 denoting the ratio Y_0/S_0. Since the gain is only unity under optimal conditions, the noise figure F_0 of the subsequent intermediate-frequency stage also contributes to the resulting noise figure F_r of a receiver with a diode mixer stage at its entrance. In this case we have, disregarding later stages,[6]

$$F_r = F_m + \frac{F_0-1}{g}, \quad (16)$$

g being the gain figure of the mixer stage (see (4)).

From (15) and (16), we may conclude that operational conditions causing optimum gain by (4) also cause a minimum value of F_m and of F_r if F_0 is given. These conditions are: $S_0R_{in}\gg 1$ and class C operation resulting in $S_0\approx S_1$ and also $Y_0\approx Y_1$. By these conditions, according to (15), F_m approaches unity, thus suppressing almost completely the diode's contribution to the over-all noise figure.

The reason for the indication of (9) as a "complete set of fluctuation components" will be apparent from the preceding analysis. In fact, these components, and they only, contribute toward the output fluctuation current at an interval Δf centered around ω_{out}.

At ultra-high frequencies the four-terminal equations (1) have to be replaced by

$$\begin{aligned} I_{in} &= S_{in}V_{in} - S_{12}V_{out}, \\ I_{out} &= S_{21}V_{in} - S_{out}V_{out}, \end{aligned} \quad (17)$$

the admittances S_{in}, S_{12}, S_{21}, and S_{out} being in general *complex* and different from one another. If the diode circuit under operating conditions is regarded as a linear passive network, (17) should be the equations of a symmetrical four-terminal device, entailing $S_{12}=S_{21}$. As it contains an internal source of power constituted by the local oscillator, it need not, however, be passive at all frequencies and hence we may assume S_{12} to be different from S_{21} in the general case. The positive directions of currents and voltages may again be seen from Fig. 1, the admittances, however, differing from that figure. The equivalent circuit of (17) is shown in Fig. 3, the unsymmetrical character being expressed by the extra constant-current generator of current $I=(S_{21}-S_{12})V_{in}$, as shown. By a similar reasoning as used in the derivation of (15), we obtain in the present case a noise figure:

$$F_m = 1 + \frac{T_c}{T_{in}} \frac{P}{|S_{in}Z_{in}|}, \tag{18}$$

P being the present equivalent of α_0 multiplied by the expression between brackets in (15), its value remaining below a fixed upper bound if $|SZ_{in}|$ is increased indefinitely.

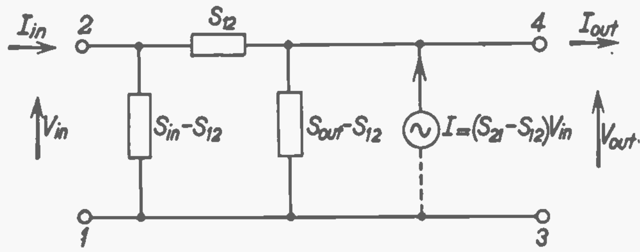

Fig. 3—Equivalent active four-terminal network of a diode mixer stage at ultra- and extremely high frequencies, its operation being described by equation (17).

From (18) and (16) we may judge the conditions favorable to a minimum over-all noise figure F_r. As P in (18) cannot in general be annihilated, the most effective means of reducing F_m resides in an increase of $|S_{in}Z_{in}|$. By using feedback, e.g., from an extra triode circuit, properly paralleled to Z_{in}, a considerable increase of $|S_{in}Z_{in}|$ may be obtained, generally accompanied by an increase of P_{in}. At the same time an increase of $|Z_{in}|$ will result in an increase of gain and hence, by (16), in a further decrease of F_2. The unfavorable effect of dielectric and similar losses on the noise figure may also be minimized by the said feedback.

III. Triode and Multigrid Mixer Stages

We shall now consider mixer stages in which a triode, tetrode, or pentode is used, input signal voltage and

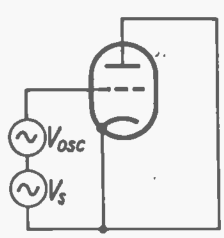

Fig. 4—Triode mixer stage, local oscillator and signal sources being represented by constant-voltage generators V_{os} and V_s active between cathode and grid.

local oscillator voltage both acting between cathode and control grid.[8] As in the preceding section II, the output will be short-circuited as this makes no difference in evaluating the noise figure or an equivalent value, whereas it simplifies calculations. We shall consider Fig. 4. Denoting the transadmittance from grid to anode by S, this transadmittance is dependent on time as expressed by (3), if the oscillator voltage is $V_{os}\cos\omega_{o}t$. The signal voltage being $V_s\cos\omega_{in}t$, we obtain a current $I_{out}\cos\omega_{out}t$ in the output lead connecting anode and cathode, given by

$$I_{out} = S_1V_s, \tag{19}$$

ω_{out} being $\omega_{in}-\omega_{os}$ as before. The value S_1 is often indicated as conversion transconductance. The current of angular frequency ω_{in} in the anode lead is

$$I_{in} = S_0V_s. \tag{20}$$

Besides currents caused by the signal, fluctuation currents flow through the anode lead. Of these we consider the fluctuations corresponding to a frequency interval Δf either centered around ω_{out} or around ω_{in}. We may again, as in the diode case, start from a complete set of fluctuation components, the mean-square fluctuation current in the anode lead being given by (5). Using (6) to (9), we obtain a mean-square fluctuation current corresponding to an interval Δf centered around ω_{out}, expressed by

$$\begin{aligned}\overline{I_{fout}^2} &= 4kT_c\Delta f(y_0^2 + 2y_1^2 + 2y_2^2 + \cdots) \\ &= 4kT_c\alpha_0S_0\Delta f,\end{aligned} \tag{21}$$

α_0 denoting Y_0/S_0. Calculating the mean-square fluctuation current $\overline{I_{fin}^2}$ corresponding to an interval centered around ω_{in}, we again obtain the result (21). These results have, of course, been known before,[1,13,20,21] the present discussion offering a new angle of approach in their derivation. From (21) and (19), the noise ratio in the anode lead pertaining to the angular frequency ω_{out} is found to be $4kT_cT_c\alpha_0S_0\Delta f/S_1^2V_s^2$, whereas from (21) and (20) we obtain for the noise ratio in the same lead, corresponding to the angular frequency ω_{in}, the expression $4kT_c\alpha_0S_0\Delta f/S_0^2V_s^2$. As, in general, $S_0 > S_1$, the second noise ratio is smaller than the first one. Instead of the said noise ratios we may also consider the equivalent noise resistances[1–3,7,11,13,20,21,22] as being, respectively,

$$\frac{T_cT_c\alpha_0S_0}{TS_1^2} \quad \text{and} \quad \frac{T_cT_c\alpha_0}{TS_0},$$

the second one being again, in general, smaller.

Now, by a suitable feedback from the output to the input, the noise ratio or noise resistance corresponding to an interval Δf centered around ω_{out} may be decreased and made to approach the above expressions, corresponding to an interval Δf centered around ω_{in}. The said feedback is assumed to be active in the vicinity of ω_{in}. Let the short-circuit condition at the output be only inappreciably altered by the feedback. If the signal voltage without feedback is V_{s0} and with feedback V_s we have

$$V_s = V_{s0} + \beta S_0V_s,$$

the impedance coefficient β expressing the feedback.

[20] E. W. Herold and L. Malter, "General superheterodyne considerations at ultra-high frequencies," Proc. I.R.E., vol. 31, pp. 567–575; August, 1943.

[21] M. J. O. Strutt, "Frequency changers in all wave receivers. The performance of some types," *Wireless Eng.*, vol. 14, pp. 184–192; 1937.

[22] M. J. O. Strutt, "High frequency, mixing and detection stages of television receivers," *Wireless Eng.*, vol. 10, pp. 174–187; 1939.

Then

$$V_s = \frac{V_{s0}}{1 - \beta S_0}. \qquad (22)$$

By the feedback a noise voltage V_{fin} is caused at the input,

$$V_{fin} = \beta(I_{fin} + S_0 V_{fin}) \quad \text{or} \quad V_{fin} = \frac{\beta I_{fin}}{1 - \beta S_0}.$$

The total mean-square noise current in the anode lead with feedback and corresponding to an interval Δf centered around ω_{out} is

$$\overline{I_f^2} = \overline{(S_1 V_{fin} + I_{fout})^2} = \overline{(\gamma I_{fin} + I_{fout})^2}, \quad \gamma = \frac{\beta S_1}{1 - \beta S_0}.$$

In the averaging process indicated by the horizontal dashes due account has to be taken of the correlation between $I_{f\,in}$ and $I_{f\,out}$. By (9) and (7) we obtain

$$\frac{I_{fin}}{p} = y_1 \cos(\omega_{in} t + a_0) + y_0 \cos(\omega_{in} t + a_1) + y_2 \cos(\omega_{in} t - b_1) + y_1 \cos(\omega_{in} t + a_2) + y_3 \cos(\omega_{in} t - b_2) + \cdots,$$

$$\frac{I_{fout}}{p} = y_0 \cos(\omega_{out} t + a_0) + y_1 \cos(\omega_{out} t + a_1) + y_1 \cos(\omega_{out} t - b_1) + y_2 \cos(\omega_{out} t + a_2) + \cdots.$$

Hence the averaging process yields, by (8),

$$\overline{I_f^2} = 4kT_c \Delta f \alpha_0 \left(\gamma^2 S_0 + 2\gamma S_1 \frac{\alpha_1}{\alpha_0} + S_0 \right), \qquad (23)$$

α_0 being again Y_0/S_0 and $\alpha_1 = Y_1/S_1$. From (23) and (22) the noise ratio corresponding to an interval Δf centered around ω_{out} is found to be

$$\frac{\overline{I_f^2}}{S_1^2 V_s^2} = \frac{4kT_c \Delta f \alpha_0 \left(\gamma^2 S_0 + 2\gamma \frac{\alpha_1}{\alpha_0} S_1 + S_0 \right)}{\dfrac{S_1^2 V_{s0}^2}{(1 - \beta S_0)^2}}. \qquad (24)$$

Two limiting cases of (24) are of special interest. First, the case corresponding to $\beta = 0$. Obviously we reobtain the value found previously without feedback. Second, the case of critical feedback corresponding to $1 - \beta S_0 \approx 0$. Here only the first term within brackets in the numerator remains, and we obtain, as $\beta S_0 \approx 1$,

$$\frac{\overline{I_f^2}}{S_1^2 V_s^2} \approx \frac{4kT_c \Delta f \alpha_0 \beta^2 S_1^2 S_0}{S_1^2 V_{s0}^2} = \frac{4kT_c \Delta f \alpha_0}{S_0 V_{s0}^2},$$

which is obviously the noise ratio obtained previously for an interval Δf centered around ω_{in}. Thus, by proper feedback, a reduction of the output noise ratio and hence of equivalent noise resistance corresponding to an interval Δf centered around ω_{out} may be obtained. This reduction is only appreciable if S_1 is appreciably smaller than S_0, which depends on conditions of operation. Ultimately, by proper feedback, the noise ratio of a triode mixer stage may always be made to approach the ratio corresponding to the same triode used in a radio-frequency amplifier stage at optimal conditions of operation.

The application of a similar method to tetrode, pentode, or multigrid tubes used in mixer stages with both signal and local-oscillator voltage acting between cathode and control grid offers still greater possibilities of reduction of output noise ratio. In such stages the coefficient α of (3) is considerably larger in the anode lead than in the cathode lead. Referring to Fig. 5, omitting Z and assuming the constant-voltage local oscillator V_{os} in series with V_s, the fluctuations in the lead from the anode a to the point D include partition-current fluctuations[14] due to the several grids of positive steady voltage, and hence are considerably larger than the fluctuations in the lead from the cathode c to the point B. Denoting the fluctuation current in the latter lead by I_{fc}, the fluctuation current I_{fa} in the anode lead may be decomposed into a part completely correlated to I_{fc} and a second part, completely incorrelated to I_{fc}, thus:

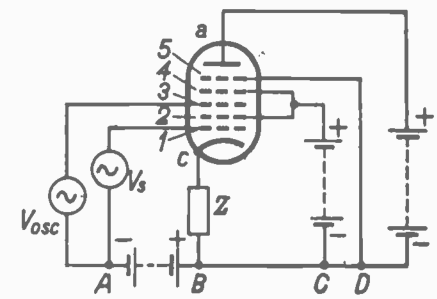

Fig. 5—Mixer stage incorporating a heptode mixer tube with separate screened grids for the local-oscillator voltage V_{os} and the signal voltage V_s. The equivalent noise resistance may be reduced by the application of proper feedback, e.g., represented by a suitable impedance Z, as shown, in the proportion of, e.g., 1 to 30.

$$\overline{I_{fa}^2} = A_c^2 \overline{I_{fc}^2} + \overline{I_{fp}^2}, \qquad (25)$$

the coefficient A_c^2 being <1 due to the interception of part of the electronic current by the electrodes of positive steady voltage. Now suppose we applied feedback from the said cathode lead up to the point B of Fig. 5 to the input, again expressed by an impedance coefficient β as before, without disturbing the short-circuit condition of the output lead appreciably. We shall again suppose the feedback to be active in the vicinity of ω_{in}. Then the mean-square fluctuation current in the cathode lead corresponding to an interval Δf centered around ω_{out} with feedback is given by (23), S and its components S_0 and S_1 (see (3)) denoting transadmittances from the control grid to all the subsequent electrodes of positive steady voltage taken together. The part $\overline{I_{fp}^2}$ of (25) not being appreciably influenced by the said feedback, the total resulting fluctuation current centered around ω_{out} in the anode output lead with feedback is substantially obtained by inserting (23) instead of $\overline{I_{fc}^2}$ into (25). As to the output current due to the original signal voltage V_{so} at ω_{in}, this is given by A_cS_1 multiplied by V_s of (22). Hence, the noise ratio in the anode output lead from a to the point D in Fig. 5 corresponding to an interval centered around ω_{out} is

$$\frac{A_c^2 4kT_c\Delta f\alpha_0\left(\frac{\beta^2 S_1^2}{(1-\beta S_0)^2}S_0+2\frac{\beta S_1}{1-\beta S_0}\frac{\alpha_1}{\alpha_0}S_1+S_0\right)+\overline{I_{f_p}^2}}{\frac{A_c^2 S_1^2 V_{s0}^2}{(1-\beta S_0)^2}}. \quad (26)$$

At critical feedback, βS_0 then approaching unity, this ratio obviously approaches the value $4kT_c\alpha_0\Delta f/S_0V_{s0}^2$ corresponding to the *triode*, equivalent to the lower part of the multigrid tube consisting of cathode, control grid, and an anode replacing the positive electrodes. As in (25) the second term on the right is often much larger than the first one (e.g., 2 to 4 times larger in pentodes and 10 or 20 times larger in multigrid tubes), a very substantial reduction of noise ratio, equivalent noise resistance, and noise figure may be obtained by the present application of feedback. As an example, an impedance Z is inserted in the cathode lead of Fig. 5, indicating a tank-circuit tuned to an angular frequency slightly below ω_{in} so as to present effectively a capacity at ω_{in}.

We have hitherto assumed the local oscillator and signal source both to be active between cathode and control grid. As an extension of the above discussion, it will now be assumed that the two voltages mentioned are active between the cathode and separate grids, as indicated in Fig. 5. In this case the transadmittance S_c from the control grid number 1 in Fig. 5 to all the subsequent electrodes of positive voltage taken together is independent of time under ideal conditions, as the oscillator does not become active upon the electron stream before it has passed grid number 2. We ignore electrons revolving around the wires of grid number 2. The noise ratio in the cathode lead remains in this case substantially unaltered by a feedback as considered above and the final noise ratio in the anode lead at critical feedback approaches $4kT_cT_e\alpha_0\Delta f/S_0V_{s0}^2$. Referring to equivalent noise resistances, the values corresponding to multigrid mixer tubes of the kind shown in Fig. 5 are often 50 to 100 kilohms[2,21] and may, by proper application of the feedback mentioned, be reduced to a few kilohms, say from 80 to 3 kilohms in a particular case.

Instead of a feedback active at ω_{in} as discussed above, we might also try a feedback active at ω_{out}. It may be shown by a simple calculation along the above lines that the output noise ratio corresponding to an interval Δf centered around ω_{out} is not altered appreciably by such feedback in the case of a triode mixer tube, as in Fig. 4. But in the case of a multigrid tube, local oscillator and signal voltage being both active between cathode and control grid a reduction of the said noise ratio may be obtained by a feedback as mentioned. In fact, the noise ratio may be made to approach that of a triode *mixer* tube consisting of the cathode, the control grid, and the subsequent electrodes together acting as anode. The impedance Z in the cathode lead might in this case consist of a tank circuit tuned to a slightly lower angular frequency than ω_{out} so as effectively to present a capacitance at ω_{out}. This feedback may have advantages, as the angular frequency ω_{out} often remains fixed if ω_{in} and ω_{os} vary over a wave band. In the case of a multigrid tube circuit as shown in Fig. 5, the latter feedback cannot be successfully applied, however, as the cathode lead from c to B contains practically no signal-current components of angular frequency ω_{out}.

By the feedback connections as discussed, instability of the mixer stage in question might ensue. This may be avoided by a suitable extra feedback. Through the output lead a signal current of angular frequency ω_{in} flows, as well as a component of angular frequency ω_{out}. At critical feedback active at ω_{in} as discussed above, the noise ratio corresponding to an interval Δf centered around ω_{out} is substantially equal to that at ω_{in}. We may now apply a ***negative*** feedback, active at ω_{in}, from the anode output lead to the input in order to stabilize the mixer stage and thereby incur no increase of the acquired favorable noise ratio. A similar stabilization may be applied if feedback active at ω_{out} is under discussion.

The application of negative bias voltage to the control grid for volume-control purposes is, of course, detrimental to the feedback circuits discussed above, as S is thereby reduced considerably. Hence, different means of volume control have been devised, not impairing the desired noise reduction by feed back. Their discussion, however, lies outside the scope of this paper.

Care should be exercised in order not to introduce undue additional noise by the feedback under application. Unsuitable resistance elements in this feedback should, therefore, be avoided as far as possible.

The means aiming at a reduction of output noise ratio discussed above may in general be applied in the same way at ultra-high frequencies, e.g., used in television.[22] Their proper understanding necessitates a preliminary discussion of fluctuation currents in a triode at ultra-high frequencies, being different from those at radio frequencies. At the latter frequencies these fluctuations may be ascribed to a constant-current generator of infinite internal impedance active between cathode and anode and supplying fluctuation currents corresponding to intervals Δf centered around ω_{out}, ω_{in}, and any other frequencies under discussion. At ultra- and super-high frequencies, however, the fluctuations must be ascribed to *two separate* constant-current generators of infinite internal impedance, one active between cathode and grid while the other is active between grid and anode. The fluctuation currents supplied by these generators are *completely correlated* in the case of an ideal triode if they correspond to intervals Δf centered around the same frequency. The latter generator current is, however, delayed in phase with respect to the former, the phase angle being approximately $\phi = \frac{1}{2}\omega\tau_0 + \frac{2}{3}\omega\tau_1$ at not too high angular frequencies ω such that $\phi \ll 1$, τ_0 and τ_1 being the electronic transit times between cathode and grid and between grid and anode, respectively. Furthermore, at not too high frequencies the moduli of the said two generator currents are approximately equal[7,12,23,24] and are both given by (5), S being the real part of the transadmittance from grid to anode at the frequency around which Δf is centered. By the action of these two generators, a fluctuation current equal to the difference of the generator currents flows through the grid lead of the triode.[12,23,24]

IV. Oscillator Noise, Push-Pull Stages, and Image Response

In the preceding sections no account was taken of noise introduced into the mixer circuit by the local oscillator. The latter acts as a source of spontaneous fluctuations as well as of oscillator voltage.[25] By the mixer operation these spontaneous fluctuations of voltage of angular frequencies centered around ω_{os} and its multiples are partly converted to current fluctuations in the output lead of angular frequencies centered around ω_{out}. We may assume that the oscillator output presents no appreciable fluctuation voltage components corresponding to frequency intervals Δf centered around ω_{in} or ω_{out} if suitable high-Q tank circuits are utilized and if sufficient separation between these frequencies exists.[2] In order to minimize the fluctuations at the mixer output due to the local oscillator's noise voltage, it may be important to reduce the latter voltage as far as possible in comparison to the oscillator voltage proper. Conditions corresponding to a low ratio of noise to oscillator voltage at the oscillator's output in many cases coincide with those corresponding to a high efficiency figure of the oscillator stage, i.e., to a high ratio of oscillator power to direct supply power.[25] Hence high efficiency in oscillator operation appears favorable from this point of view.

Another means of reducing the noise figure of mixer stages resides in an application of the push-pull principle. It has been recognized previously that the noise ratio of push-pull amplifier stages may be less than the corresponding figure of comparable single stages under suitable conditions. The same conclusion applies to push-pull mixer stages. The reason is that the output noise currents due to the two separate push-pull tube systems are completely uncorrelated, and hence the resulting mean-square noise current is obtained as the sum of the two individual mean-square currents due to the tubes, thus being twice the current squared due to one tube system. The resulting signal current squared is, however, four times the signal current squared due to one tube system.

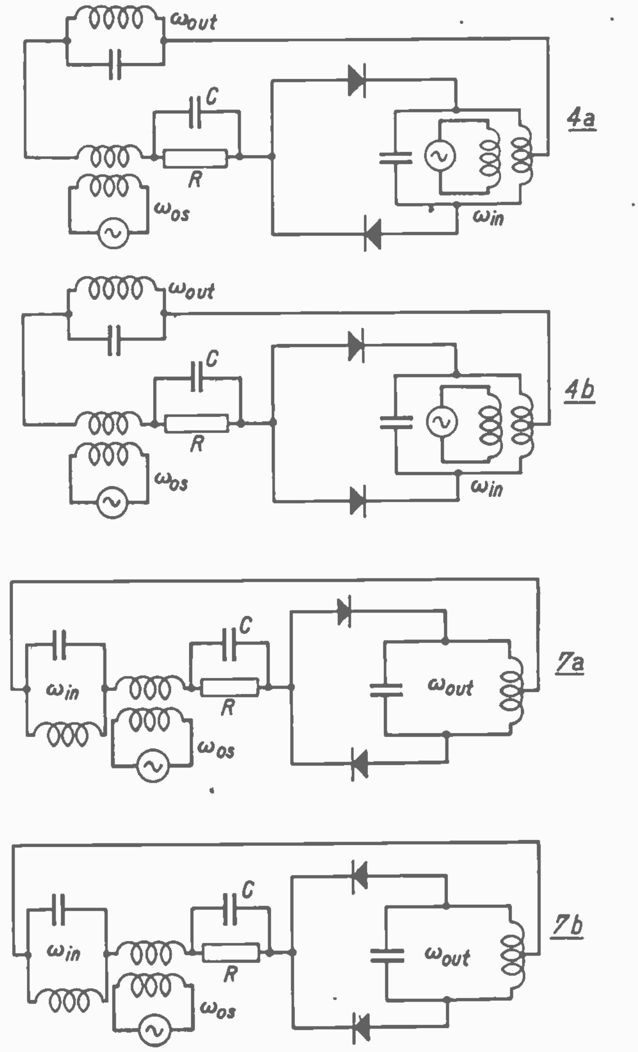

Fig. 6—Four push-pull diode mixer stages, ω_{out}, ω_{in}, and ω_{os} indicating the output, input, and oscillator circuits, while R is a biasing resistance blocked by a suitable capacitance C. The circuits marked 4a and 4b differ only in the relative orientation of the diodes and so do the circuits marked 7a and 7b. The circuits marked a are not practically useful under common conditions of operation, but the circuits marked b are useful.

The application of the push-pull principle to mixer stages affords some interesting aspects. We shall refer in the first place to diode mixer stages. There being three voltages, input, oscillator, and output, eight possibilities arise.

Case Number	Input	Oscillator	Output
1	push-pull	push-pull	push-pull
2	push-pull	push-pull	single
3	push-pull	single	push-pull
4	push-pull	single	single
5	single	push-pull	single
6	single	push-pull	push-pull
7	single	single	push-pull
8	single	single	single

The meaning of "single" is that the voltage in question is applied to the corresponding electrodes of both mixer tubes in shunt. Not all of these possibilities correspond to practically useful circuits. The relation between ω_{out}, ω_{in}, and ω_{os} is in general:

[23] D. O. North and W. R. Ferris, "Fluctuations induced in vacuum tube grids at high frequencies," Proc. I.R.E., vol. 29, pp. 49–50; February, 1941.

[24] M. J. O. Strutt and A. van der Ziel, "Methods for the compensation of the effects of different types of shot-effects in electronic valves and attached circuits," (in German), *Physica*, (Hague), vol. 8, pp. 1–22; 1941.

[25] Tsonge Shih, "Noise of electron tubes in self-excitation," (in German), *Inst. of Tech.*, Dissertation, 45 pp., Dresden, Germany, 1937.

$$\omega_{out} = | m\omega_{os} \pm n\omega_{in} |, \quad (27)$$

m and n denoting definite integral numbers out of a sequence, these sequences being:

Case number	*m*	and *n*	or *m*	and *n*
1	1, 3, 5, · · ·	0, 2, 4, · · ·	0, 2, 4 · · ·	1, 3, 5 · · ·
2	1, 3, 5, · · ·	1, 3, 5, · · ·	0, 2, 4, · · ·	0, 2, 4, · · ·
3	0, 1, 2, 3, 4, · · ·	1, 3, 5, · · ·		
4	0, 1, 2, 3, 4, · · ·	0, 2, 4, · · ·		
5	0, 2, 4, · · ·	0, 1, 2, 3, 4, · · ·		
6	1, 3, 5, · · ·	0, 1, 2, 3, 4,		
7	no output			
8	0, 1, 2, 3, 4, · · ·	0, 1, 2, 3, 4, · · ·		

Case number 4 is of little practical use since the output voltage is proportional to the square of the input voltage, whereas a linear relationship between these voltages is desirable. It is supposed in the above circuits that both diodes are applied in *parallel* orientation. We may, however, reverse one diode with respect to the other, thus obtaining eight more cases besides those discussed above. It is interesting to note that the cases 4 and 7 of the above table may be converted into useful circuits by the said reversal as is illustrated by Fig. 6, the diagrams marked b corresponding to the above tables and those marked a to reversed-diode cases. In case 4a of Fig. 6, the sequences of m and n in (27) are 1, 3, 5 · · · and 0, 1, 2, 3 · · · . In the case 7a they are as in the case 2 of the above table. A complete discussion of the sixteen possible push-pull diode mixer circuits mentioned lies outside the scope of the present paper.

With triode and multigrid push-pull mixer circuits we have eight basic possibilities, as in the above tables, if the tubes are applied in parallel and equal orientation. With a triode the orientation of the *three* electrodes may be permuted, thus creating at least 40 new cases besides the eight of the above tables. No mention has yet been made of image or indeed any spurious response of the mixer stages in question. Assuming that, e.g., image response is effectively equal to input response, as may occur in extremely high-frequency circuits, the noise ratio at the output is increased. Hence, responses of this kind are undesirable from the noise point of view as from most others.[16] Relatively high intermediate frequencies are conducive to their reduction.

Additional References

(1) M. Dishal, "Theoretical gain and signal-to-noise ratio obtained with the grounded-grid amplifier at ultra-high frequencies," Proc. I.R.E., vol. 32, pp. 276–284; May, 1944.

(2) M. C. Jones, "Grounded-grid radio-frequency voltage amplifiers," Proc. I.R.E., vol. 32, pp. 423–430; July, 1944.

(3) W. Kleen, "Grid-steering, cathode-steering and cathode-amplifiers," (in German), *Eleck. Nach. Tech.*, vol. 20, pp. 140–144; 1943.

(4) M. J. O. Strutt, "The characteristic admittances of mixer valves at frequencies up to 70 mc./sec.," (in German), *Elek. Nach. Tech.*, vol. 15, pp. 10–18; 1938.

(5) M. J. O. Strutt and A. van der Ziel, "The diode as a frequency changing valve, especially at decimeter waves," *Philips Tech. Rev.*, vol. 6, p. 285; 1941.

Sporadic *E*-Region Ionization at Watheroo Magnetic Observatory 1938-1944*

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Summary—Characteristics of sporadic *E* (*Es*) at the Watheroo Magnetic Observatory, Western Australia, have been determined from continuous ionospheric recordings since June, 1938. Average diurnal curves show most frequent occurrence at night with maximum near midnight, local time, although there is a tendency for the most intense *Es* to occur during day hours. The seasonal features of *Es* already well established for the Northern Hemisphere have been confirmed for the Southern Hemisphere with a maximum of *Es* in local summer months. Annual trends show increasing values from 1938 to 1941 with decreasing values from 1941 through 1944. An upward trend is indicated for 1945, suggesting a minimum in 1944. This annual characteristic is significant in view of an apparent inverse relationship with sunspots in the Northern Hemisphere. Separate analyses were made of *Es* to determine 40- to 80-megacycle propagation conditions for a 1000-mile path in per cent of time for selected hours of November, 1941, which was the period of greatest *Es* activity. Results show 40-megacycle signals supported for 15 per cent of time, while 80-megacycle signals dropped to less than 1 per cent of time. As a test for solar origin of *Es*, the data were examined for recurrence tendencies in successive 27-day solar rotational periods. No pronounced recurrences of *Es* at 27-day intervals are apparent, from which it may be inferred that *Es* has no direct relationship with other recurrent solar phenomena such as sunspots and other centers of solar activity. Comparisons between *Es* and magnetic activity do not reveal any tendency of *Es* to be more prevalent during periods of magnetic disturbance.

I. Introduction

Ionospheric records at Watheroo Magnetic Observatory during June, 1938, to December, 1945, have been examined to determine additional characteristics of sporadic *E*-region ionization (*Es*) (Figs. 1-8). For the purpose of this investigation, only the intense type of *Es* giving several multiple reflections was considered. The "multiple" type of *Es* is defined in the Report of International Radio Propagation Conference (IRPL-C61) issued June, 1944, and the symbol f^mEs identifies the phenomena defined above. These data include *Es* of the blanketing type as well as the partially transparent type with a high reflection coefficient, but do not include weak abnormal *E* echoes of the border or fringe type. The upper limit of *Es* was determined by the upper frequency at which the first multiple echo disappears.

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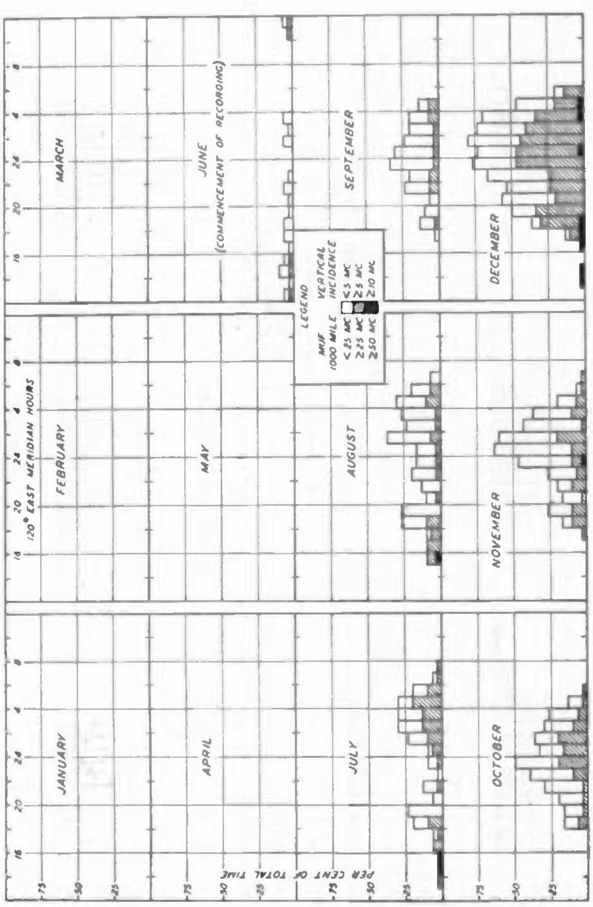

Fig. 1—Diurnal distribution of sporadic *E* in per cent of total time, Watheroo, 1938.

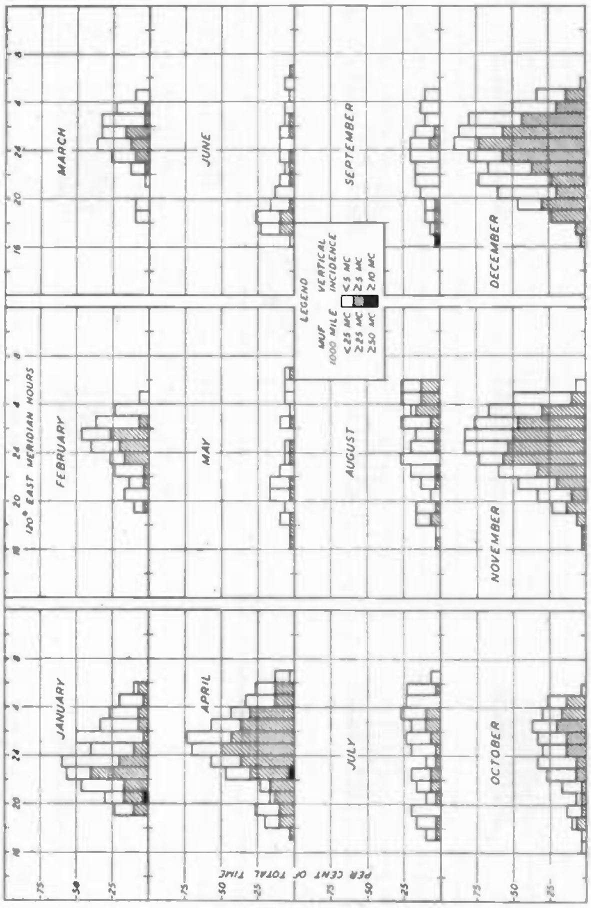

Fig. 2—Diurnal distribution of sporadic *E* in per cent of total time, Watheroo, 1939.

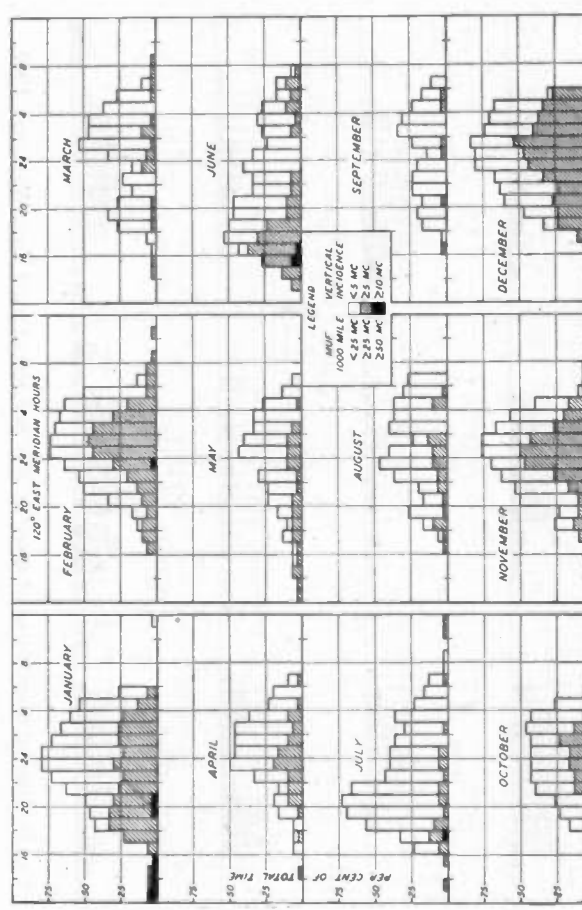

Fig. 3—Diurnal distribution of sporadic *E* in per cent of total time, Watheroo, 1940.

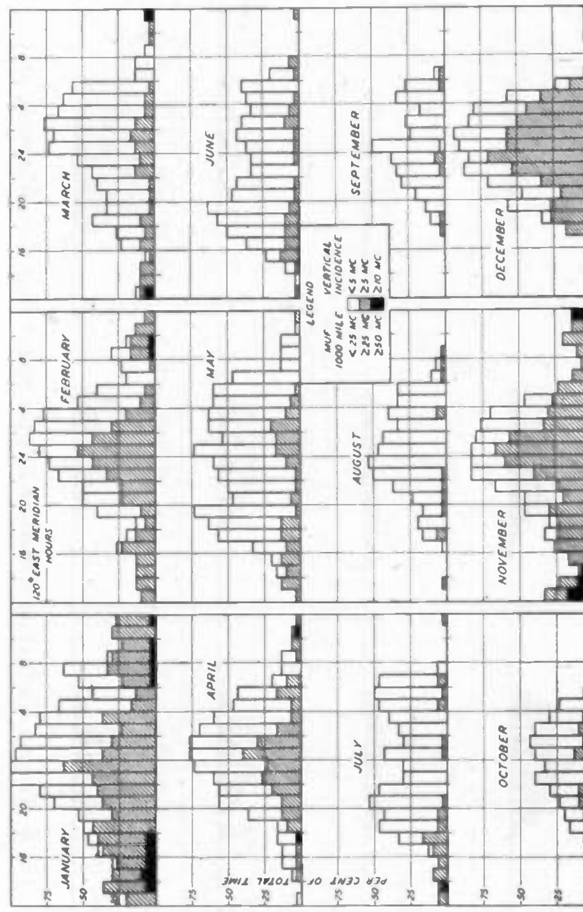

Fig. 4—Diurnal distribution of sporadic *E* in per cent of total time, Watheroo, 1941.

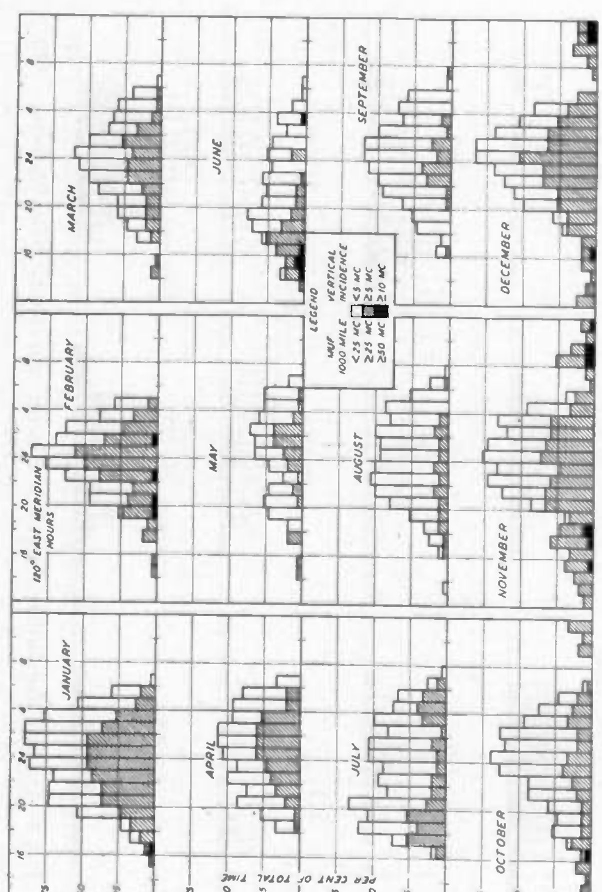

Fig. 5—Diurnal distribution of sporadic *E* in per cent of total time, Watheroo, 1942.

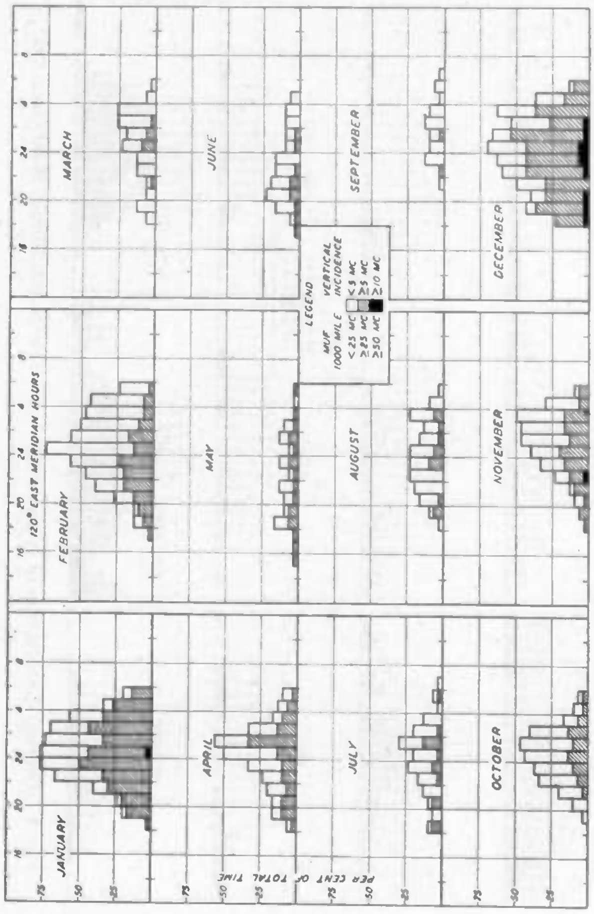

Fig. 6—Diurnal distribution of sporadic *E* in per cent of total time, Watheroo, 1943.

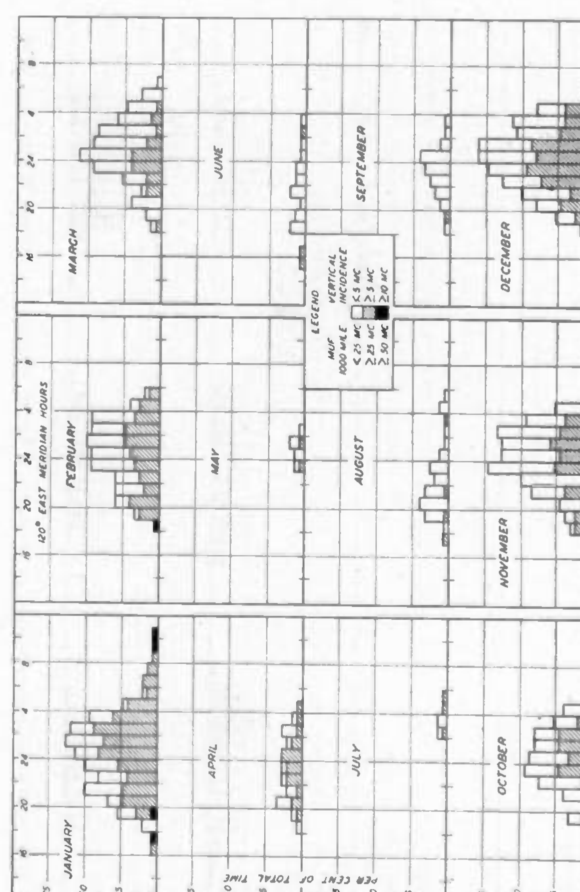

Fig. 7—Diurnal distribution of sporadic *E* in per cent of total time, Watheroo, 1944.

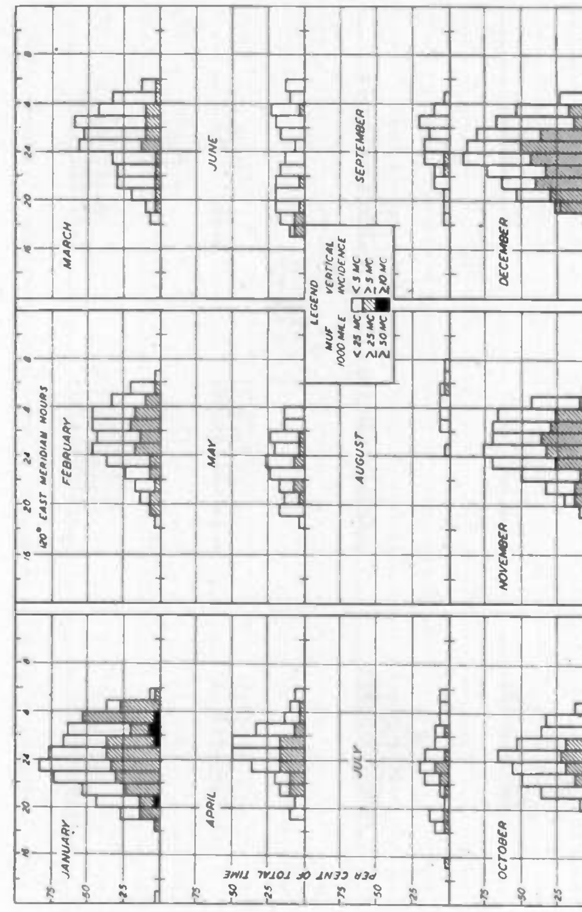

Fig. 8—Diurnal distribution of sporadic *E* in per cent of total time, Watheroo, 1945.

A typical occurrence of *Es* is illustrated in Fig. 9, as recorded with the automatic ionospheric recorder designed and constructed by the Department of Terrestrial Magnetism, Carnegie Institution of Washington. It is seen that *Es* completely masked the normal *F* region at frequencies up to 8.1 megacycles. Between 8.1 and 9.0 megacycles, *Es* is still sufficiently intense to return several multiple reflections, although recordings of the *F* region show that energy is penetrating through the *Es* region. In the present analysis, *Es* illustrated in Fig. 9 would be recorded as 9.0 megacycles.

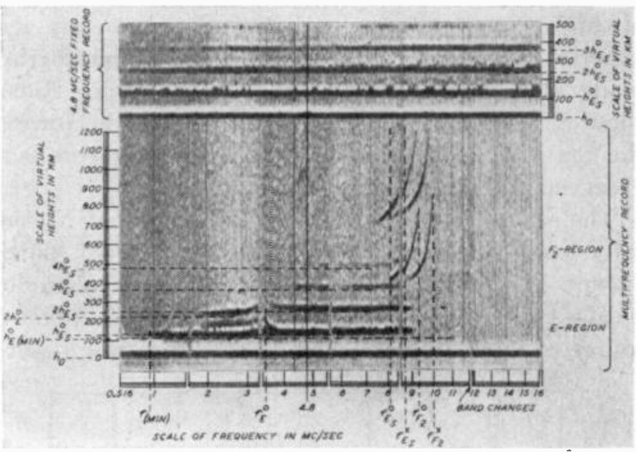

Fig. 9—Ionospheric characteristics during sporadic *E*-region ionization, Watheroo, $8^h\,45^m$, January 22, 1939.

In the legends of Figs. 1 to 8 a factor of five was used in converting from vertical-incidence *Es* to approximate maximum usable frequency at 1000-mile range. For example, *Es* of 10 megacycles at vertical incidence is interpreted as supporting communications up to 50 megacycles at oblique incidence over a 1000-mile path. Specifically, these conditions maintain when the point of ionospheric reflection for the 1000-mile circuit is overhead.

The effectiveness of *Es* in supporting single-hop radio communications is limited to 1500 miles or less at zero vertical angle of radiation for *E*-region heights of approximately 100 kilometers.

II. Diurnal Characteristics

The diurnal characteristics of *Es* for each month from June, 1938, through December, 1944, are illustrated in Figs. 1 to 8. From the legend it will be noted that solid black represents *Es* of 10 megacycles or greater, shaded areas represent *Es* of 5 megacycles or more, and the unshaded areas represent *Es* of less than 5 megacycles. In terms of oblique-incidence radio wave propagation, the legend also indicates approximate maximum usable frequency (MUF) at 1000-mile distance. Data for each month are plotted for the 24-hour period beginning at noon, 120 degrees east meridian time.

A general prevalence of *Es* during night hours with maximum occurrence near local midnight is clearly indicated, although there is a tendency for the more intense *Es* (in excess of 10 megacycles) to occur in the day hours.

III. Monthly and Seasonal Characteristics

The monthly distribution of *Es* in per cent of total time is shown in Fig. 10. Local summer months (October

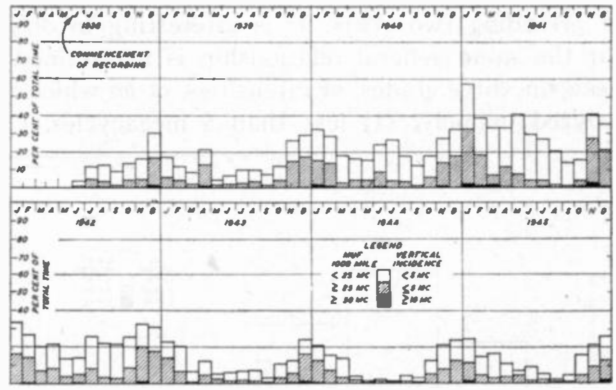

Fig. 10—Monthly distribution of sporadic *E* in per cent of total time, Watheroo Magnetic Observatory, 1938–1945.

to February) of each year are characterized by frequent and persistent occurrence of *Es*. In general, the equinoctial periods as well as local winter months show minimum presence of *Es*. This long series of data now positively confirms characteristics of *Es* reported by Berkner and Wells[1] from analyses of 1935–1936 ionospheric recordings at Watheroo. The seasonal nature of *Es* in the Northern Hemisphere, with maximum in summer, minimum in winter, has been identified and discussed by a number of investigators.[2–7]

During June, 1938, to December, 1945, the maximum occurrence of *Es* was recorded in January, 1941, when it was present 57 per cent of total time. The maximum occurrence, however, of ***intense*** *Es* (in excess of 10 megacycles) was recorded in November, 1941. Further reference to Fig. 4 illustrates the diurnal distribution during these months. For example, *Es* was present 100 per cent of the time for 23^h and 24^h of January, 1941. The tendency of intense *Es* to occur in day hours, as already noted, is clearly demonstrated for both January and November, 1941.

IV. Annual Distribution

The annual distribution of *Es* is shown in Fig. 11;

[1] L. V. Berkner and H. W. Wells, "Abnormal ionization of the *E*-region of the ionosphere," *Terr. Mag.*, vol. 42, pp. 73–76; March, 1937.

[2] E. V. Appleton and R. Naismith, "Weekly measurements of upper-atmospheric ionization," *Proc. Phys. Soc.*, vol. 45, pp. 389–398; May, 1937.

[3] S. S. Kirby, L. V. Berkner, and D. M. Stuart, "Studies of the ionosphere and their application to radio transmission," Proc. I.R.E., vol. 22, pp. 481–521; ibid., *Jour. Res. Nat. Bur. Stan.*, vol. 12, pp. 15–51; January, 1934.

[4] J. P. Schafer and W. M. Goodall, "Kennelly-Heaviside layer studies employing a rapid method of virtual-height determination," Proc. I.R.E., vol. 20, pp. 1131–1148; July, 1932.

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[6] J. A. Fleming, "Report of ionosphere-investigation conducted at College—Fairbanks, Alaska, during the winter of 1933–1934," *Terr. Mag.*, vol. 39, pp. 305–313; December, 1934.

[7] E. V. Appleton, R. Naismith, and G. Builder, "Ionospheric investigations in high latitudes," *Nature*, vol. 132, pp. 340–341; September, 1933.

there was a rapid increase from 1939 to 1941, followed by a rapid decrease from 1941 to 1943. *Es* in 1944 was only slightly less prevalent than in 1943. *Es* in 1945, however, shows an upward trend which is greater than the preceding two years. It is interesting to observe that the same general relationship is maintained between the three grades, or intensities, of *Es* which were analyzed; namely, (1) less than 5 megacycles, (2) 5 megacycles or greater, and (3) 10 megacycles or greater. The downward trend since 1941 is particularly significant because it is contrary to trends in the Northern Hemisphere reported by the Interservice Radio Propagation Laboratory, National Bureau of Standards, which was suggestive of an inverse relationship between *Es* and sunspot numbers. These results at Watheroo indicate that no relationship with sunspot numbers, either positive or negative, holds for the Southern Hemisphere, since the sunspot numbers were decreasing from 1939 to 1944. In view of the important role played by *Es* in radio communications, it is very desirable that this apparently anomalous condition be clarified by additional data and analyses for other stations in both the Northern and Southern Hemisphere.

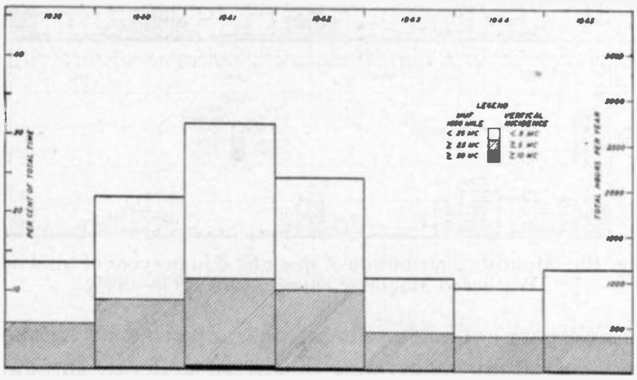

Fig. 11—Annual distribution of sporadic *E*, Watheroo Magnetic Observatory, 1939–1945.

V. Propagation in 40- to 80-Megacycle Band, November, 1941

It has been mentioned that the most intense *Es* was observed in November, 1941. The data for that month were examined separately to determine per cent of total time supporting 1000-mile transmissions in the frequency range from 40 to 80 megacycles. Results are illustrated in Fig. 12 for the five-hour period, $10^{h}\,00^{m}$ to $14^{h}\,00^{m}$, 120 degrees, east meridian time. The smooth curve indicates that *Es* supported 40-megacycle propagation for 15 per cent of the five-hour interval, dropping to 10 per cent at 50 megacycles, and tapering off to less than 1 per cent at 80 megacycles.

There is no indication in present trends of *Es* at Watheroo to suggest when similar intensities of *Es* may again be expected. A comparison of *Es* at Watheroo with *Es* at Washington, D. C., Ottawa, Canada, and College (Fairbanks), Alaska, suggests that *Es* at Watheroo is representative of *Es* in the temperate zone of the Northern Hemisphere. Although quantitative comparisons are not at present feasible because of data limitations, it is safe to state that *Es* at Watheroo when averaged over a number of years is less frequent than at College, Alaska, but more frequent than at Washington, D. C.

VI. Tests for 27-Day Recurrence

The association of *Es* with local summer months led to a suggestion by C. T. R. Wilson[8] that *Es* was a result of the high electric fields of thunderclouds. This theory, however, became untenable as investigations[1] showed very low occurrence of *Es* in equatorial regions of high thunderstorm activity. Simultaneous ionospheric recordings and zenith auroral photographs made at College Observatory, University of Alaska, show *Es* whenever there is aurora overhead. However, the converse does not hold; that is zenith aurora is not observed whenever *Es* is recorded.

The search for an extraterrestrial source of *Es* naturally leads to the sun, which is the principal ionizing agency of the ionosphere. Bursts of solar ultraviolet radiation may be eliminated readily as a potential source of ionization because *Es* occurs during night as well as day. The slower-moving corpuscular radiation from the sun which is generally accepted as the primary cause of magnetic and ionospheric disturbances is therefore a probable source of *Es*, although the seasonal character of *Es* obviously cannot be explained on this basis alone.

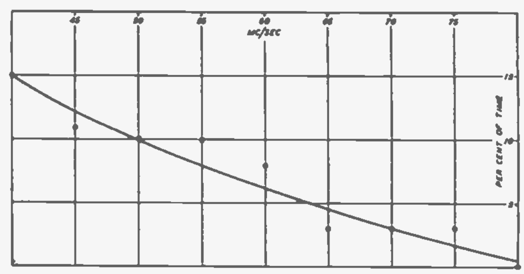

Fig. 12—Sporadic-*E* propagation, Watheroo Magnetic Observatory, November, 1941.

Bartels[9] has demonstrated the effectiveness of superimposed epoch diagrams in determining recurrence tendencies of magnetic activity for successive solar rotations. His research greatly strengthened theories that solar regions often remain active emitters of corpuscular streams for several months at a time and cause magnetic (or ionospheric) disturbances once during successive 27-day solar rotations when the streams sweep across the earth's path. Fig. 13 is an application of the same technique to the *Es* data for the period, June, 1938, to December, 1944. The shaded blocks indicate days when *Es* was at least 50 per cent greater than the

[8] C. T. R. Wilson, "The electric field of a thundercloud and some of its effects," *Proc. Phys. Soc.*, vol. 37, pp. 32D–37D; February, 1925.

[9] J. Bartels, "Terrestrial-magnetic activity and its relation to solar phenomena," *Terr. Mag.*, vol. 37, pp. 1–52; March, 1932. "Statistical methods for research on diurnal variations," *Terr. Mag.*, vol. 37, pp. 291–302; September, 1932. "Random fluctuations, persistence, and quasi-persistence in geophysical and cosmical periodicities," *Terr. Mag.*, vol. 40, pp. 1–60; March, 1935.

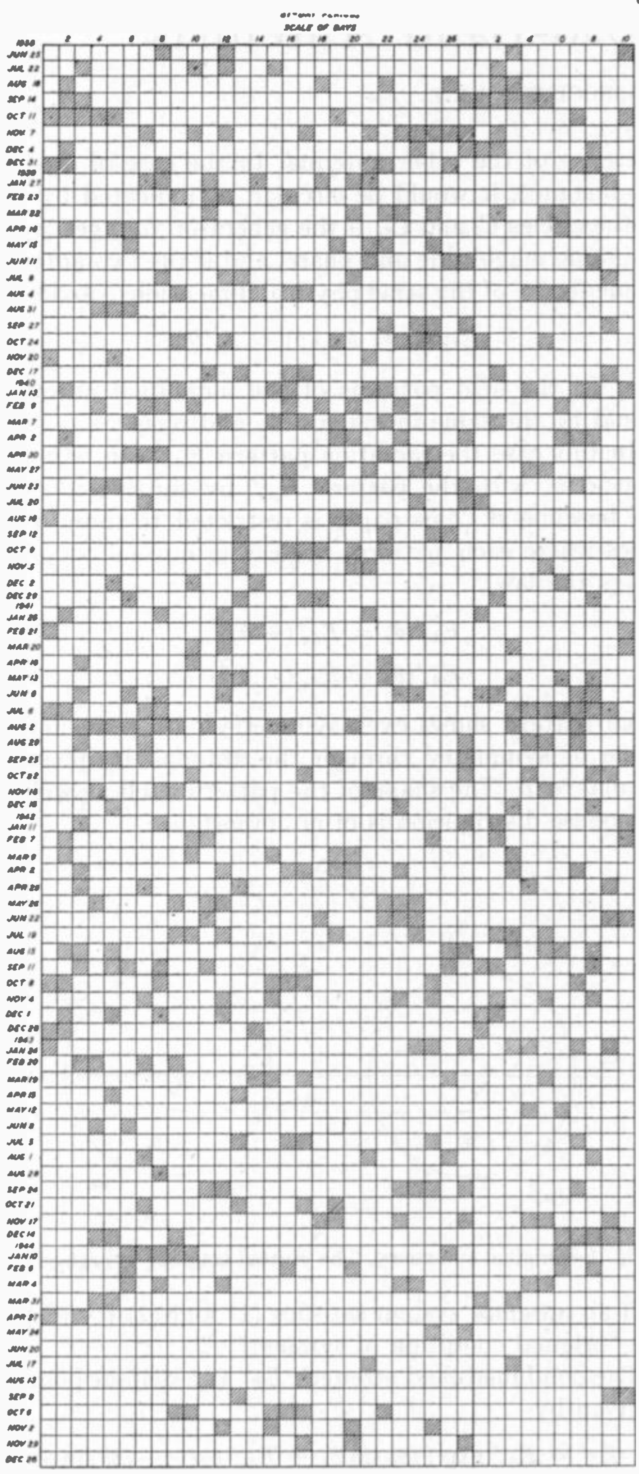

Fig. 13—Test for 27-day recurrence of sporadic *E*, Watheroo Magnetic Observatory, June, 1938, to December, 1944.

mean for each 27-day period. The date of the first day in each row is given at the left. A new row is begun after every 27 days, so that each vertical column is composed of successive dates which are separated by one solar rotation.

For sake of continuity, the horizontal lines of the block diagram extend through the first ten days of each successive cycle. This is a customary practice in recurrence tests in order to provide a sense of visual continuity for recurrences which happen near the end of each 27-day period.

Seasonal and annual trends have been eliminated from Fig. 13 by selection of the mean *Es* activity in each 27-day period as the reference level. In a diagram of this type a vertical column of shaded blocks indicates a sequence of *Es* of intensity 50 per cent greater than the mean for each period at exactly 27-day intervals. Diagonal columns indicate recurrences at slightly more or less than the 27-day interval depending upon direction of slope. Inspection of Fig. 13 shows that there are no outstanding recurrences. This is considered as significant, since magnetic activity during the same period is characterized by some outstanding recurrent disturbances which persisted for six, or more, solar rotations. Fig. 13, however, does indicate some diagonal groupings with a slope of about 45 degrees which may warrant some further attention, since they are suggestive of recurrences at 26-day intervals. Any further deductions must await the outcome of analyses to determine correlation coefficients.

VII. *Es* and Magnetic Activity

For purposes of determining whether or not *Es* was more prevalent during periods of magnetic activity, the *Es* data were separated into two categories, both of which had seasonal effects removed.

In the first case, 46 per cent of the days when *Es* exceeded the mean 27-day value coincided with days when magnetic activity was in excess of the mean value. In the second case, 52 per cent of the days with *strong Es*, as plotted in Fig. 13, coincided with days when magnetic activity exceeded the mean for the period. These figures certainly indicate no relationship between *Es* and world-wide magnetic activity. This conclusion, as based on the above data only, is somewhat surprising in view of the probability that *Es* is caused by solar corpuscular radiations. There is a great deal of evidence to support the theory that *Es* is a result of solar corpuscular radiation. As mentioned above, polar observations, including reports from College, Alaska, Observatory, have clearly associated *Es* with aurora overhead. Likewise, the relationship between aurora and magnetic activity is well established. Diurnal characteristics of *Es* in polar regions closely relate it with abnormal *D*-region absorption, indicating corpuscular origin of the abnormal ionization. Essentially, it seems that both effects are due to the same fundamental agency but sporadic *E* results when the ionization is formed in the *E* region, while complete absorption or polar radio blackout results when the ionization is formed at a slightly lower level. However, the absence of correlation between *Es* and magnetic activity does not necessarily deny the corpuscular origin of *Es* but may suggest that the local nature and limited extent of patches of *Es* are indications of minute and more or less random corpuscular streams which have no effect on the over-all magnetic field of the earth.

Design of Directive Broad-Band Antennas*

RICHARD BAUM†, ASSOCIATE, I.R.E.

Summary—**Mutual coupling between the individual antennas of a direction-finding system causes an asymmetry in their respective field patterns which prevents complete cancellation of radiation in the direction of the "null." Instead, it produces a radiation minimum combined with an error in direction. By a suitable arrangement of parasitic antennas the original symmetry can be restored and a correct and true null can be obtained.**

Introduction

THIS PAPER deals with the design of directive broad-band antennas of the zero-shifting type used in certain direction-finding systems.

Such antennas consist of two radiating elements (for instance, two dipoles) which are excited with equal currents, but out of phase. Their combined radiation pattern then has one direction in which the field strengths of the individual antennas are exactly equal but opposite in phase, and thus cancel each other. The combined pattern shows a "null," the direction of which depends upon the phase of the antenna currents.

The frequency range considered is large, say two or three to one, with a middle frequency of several hundred megacycles. In this region a linear phase shift can easily be achieved, for instance by the introduction of an additional length of line into one matched feed line. The phase shift then becomes equal to the added line length in electrical degrees, or proportional to the frequency. Without mutual coupling between the elements the direction of the null becomes independent of frequency.

The current induced in one element by the other element because of coupling produces an additional radiation field, which disturbs the symmetry of the original field. It can be shown that the distortion prevents a perfect null and a correct direction indication.

The present paper describes an antenna system which adds additional parasitic fields in such a way as to restore the original symmetry of the radiation pattern. This is achieved essentially by an arrangement of two or more parasitic antenna elements in line with the original ones.

The Condition of Symmetry

In Fig. 1, A_1 and A_2 represent two antenna elements connected to two generators G_1 and G_2 by two feedlines F_1 and F_2. The line drawn through A_1 and A_2 shall be called the baseline B. It is normal to the plane of symmetry S. The direction of a distant point P in the horizontal plane is indicated by its angle θ included with the plane S. The field strength at the point P due to antenna A_1 and A_2 is called E_{A_1}' and E_{A_2}' respectively.

If there were no coupling between the antennas, the field of each antenna would remain undisturbed by the presence of the other antenna. In the case of dipoles, for instance, it would be circular, as indicated by one of the circles C_1 and C_2. If the generator voltages are of the same magnitude and phase, and if the two antenna elements are of the same physical dimensions, obviously

$$E_{A_1}'(\theta) = E_{A_2}'(\theta) = E_A'(\theta); \tag{1}$$

that is, the field patterns of the individual antennas would be the same in magnitude and phase.

In this case the radiation pattern E_{A_1}' can be made coincident with the pattern E_{A_2}' by shifting it along the baseline B. This paper is restricted to those usual cases where each pattern, neglecting mutual coupling, obeys the law

$$\left.\begin{aligned} E_{A_1}'(\theta) &= E_{A_1}'(-\theta) \\ E_{A_2}'(\theta) &= E_{A_2}'(-\theta) \end{aligned}\right\}. \tag{2}$$

Each pattern shows even symmetry with respect to a plane of symmetry through the antenna in question normal to B. The shape of the pattern itself as well as the phase distribution is of no importance.

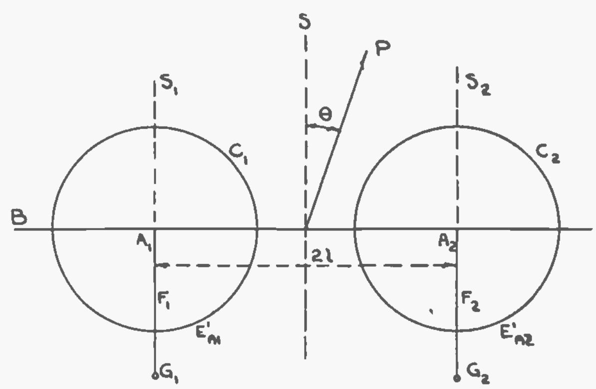

Fig. 1—Original symmetry. The mutual coupling is neglected.

If an antenna system satisfies (1) and (2) it satisfies the "original condition of symmetry."

The combined field strength E_P' at a distant point P is given by

$$E_P' = E_{A_1}' \exp(j\beta l \sin\theta) + E_{A_2}' \exp(-j\beta l \sin\theta) \tag{3}$$

where

$2l$ = distance between the two antennas

$$\beta = \frac{2\pi}{\lambda} = \text{wavelength constant.}$$

If the two generator voltages are of the same magnitude but leading and lagging respectively by an angle ϕ with respect to pure phase opposition, the field strengths can be set

$$E_{A_1}' = E_A' \exp(-j\phi)$$
$$E_{A_2}' = -E_A' \exp(+j\phi)$$

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which makes

$$E_P' = 2jE_A' \sin\left[\beta l \sin\theta - \phi\right]. \quad (4)$$

The position of zero radiation is given by

$$\sin\theta_0 = \phi/\beta l. \quad (5)$$

If the feed lines are matched throughout the frequency range, then the phase shift ϕ can be produced by lengthening one of the feed lines and shortening the other by a given length l_F equivalent to an angle

$$\phi = \beta l_F$$

which introduced into (5) gives

$$\sin\theta_0 = l_F/l \quad (6)$$

thus making the position of zero field strength (called "null") independent of frequency. The position θ_0 of the null is seen always to be zero for zero phase shift, but its position for different phase shifts depends upon the antenna spacing l.[1]

In order to obtain the required condition of (5), two assumptions have been made: First, that no coupling exists between the antenna elements; second, that (1) holds true. The latter is always the case if the "original condition of symmetry" is fulfilled. But what is happening if the mutual coupling may no longer be neglected?

The original field E_{A_1}' of antenna A_1 then induces a secondary current in the antenna A_2, which produces a secondary field E_{A_2}'' and vice versa, the field E_{A_2}' of antenna A_2 induces a secondary current in antenna A_1, which produces a secondary field E_{A_1}''. The secondary fields again induce tertiary currents which produce tertiary fields, and so on, ad infinitum. The final current in each antenna is made up of the sum of the infinite number of induced currents plus the original current; thus it is quite different, in magnitude and phase, from the original one. The final field at the point P, is also obtained by superposition of all partial fields and will be different from the original field E_P'. In particular if the direction of P was originally a direction of zero field strength, because of a given phase shift $(\pi+2\phi)$ between the generator voltages, this "null" will disappear and a definite field strength will take its place, unless the phase angle between the generator voltages is modified in such a way that the *total* currents in the antennas include the original phase $(\pi+2\phi)$. Although this adjustment might be feasible for a particular frequency, or for a narrow frequency band, it becomes impracticable for the very wide bands in consideration.

Obviously, only if the nulls of the partial fields coincide with the null of the original field, will the null remain in the proper direction after superposition of all fields.

It will be shown that in the present arrangement of two radiators the nulls of the original (primary), the tertiary, and in general all partial fields of uneven order coincide with the original null; furthermore, that the nulls of all partial fields of even order coincide with themselves, but not with the original one.

Let E_{A_1}' and E_{A_2}' again denote the original fields and k be a complex constant. Because of the symmetry condition (2), the secondary fields are equal to each other and related to the original ones according to

$$E_{A_2}'' = \exp(k) E_{A_1}'$$
$$E_{A_1}'' = \exp(k) E_{A_2}'.$$

But the same relationship holds true between the tertiary and secondary field, between the field of fourth order and the tertiary field, and so on. Thus the fields produced by antenna A_1 and A_2 are respectively:

$$\begin{array}{ll} E_{A_1}' & E_{A_2}' \\ E_{A_1}'' = \exp(k)E_{A_2}' & E_{A_2}'' = \exp(k)E_{A_1}' \\ E_{A_1}''' = \exp(2k)E_{A_1}' & E_{A_2}''' = \exp(2k)E_{A_2}' \\ E_{A_1}'''' = \exp(3k)E_{A_2}' & E_{A_2}'''' = \exp(3k)E_{A_1}' \\ \vdots & \vdots \end{array}$$

By adding all partial fields the total fields E_{A_1} and E_{A_2} due to antenna A_1 and A_2 become respectively:

$$\begin{aligned} E_{A_1} &= E_{A_1}'/[1-\exp(2k)] + E_{A_2}'\exp(k)/[1-\exp(2k)] \\ E_{A_2} &= E_{A_2}'/[1-\exp(2k)] + E_{A_1}'\exp(k)/[1-\exp(2k)]. \end{aligned} \quad (7)$$

The first summand in each expression is the sum of all partial fields of uneven order plus the original field. The second summand is the sum of all partial fields of even order. Introducing a phase angle $(\pi+2\phi)$ between E_{A_1}' and E_{A_2}' as in (4), the total fields E_{A_1} and E_{A_2} become

$$\begin{aligned} E_{A_1} &= \frac{E_A'}{1-\exp(2k)}\left[\exp(-j\phi) - \exp(j\phi)\exp(k)\right] \\ E_{A_2} &= \frac{-E_A'}{1-\exp(2k)}\left[\exp(j\phi) - \exp(-j\phi)\exp(k)\right]. \end{aligned} \quad (8)$$

By superposition of both fields the combined field at a distant point P is

$$E_P = \frac{2jE_A'}{1-\exp(2k)}\left[\sin(\beta l\sin\theta - \phi) - \exp(k)\sin(\beta l \sin\theta + \phi)\right]. \quad (9)$$

The first summand is due to the original field plus the uneven-order fields and is seen to furnish nulls according to (5) at angles θ_0 given by

$$\sin\theta_0 = +\frac{\phi}{\beta l},$$

whereas, the second summand gives nulls at angles $\theta_0' = -\theta_0$ given by

$$\sin\theta_0' = -\frac{\phi}{\beta l}\cdot \quad (10)$$

Thus the two statements are proved.

[1] Numerous examples of radiation patterns of a pair of dipoles are shown in F. E. Terman, "Radio Engineers Handbook," page 804; John Wiley Sons, Inc., New York, N. Y., 1943.

The combined field E_P is null only if

$$\exp(k)\sin(\beta l\sin\theta_0+\phi)=\sin(\beta l\sin\theta_0-\phi)$$

which leads to

$$\tan(\beta l\sin\theta_0)=-\frac{\tan\phi}{\tanh(k/2)}. \quad (11)$$

This formula shows that a null is obtained only if k is real and positive, which obviously is a very exceptional case, as k in general is a function of frequency dependent on the antenna spacing, dimensions, impedance, etc. But even in this case the position of the null is shifted from its original direction given by (5). Only in the case of zero phase shift ($\phi=0$) will the null coincide with the original one.

Therefore expression (9) normally furnishes, instead of a perfect null, a direction of minimum radiation found by setting

$$\frac{\partial|E_P|}{\partial\theta}=0,$$

which gives

$$\tan(2\beta l\sin\theta_0)=-\tan 2\phi\frac{\sinh r}{\cosh r-\cos s/\cos(2\phi)} \quad (12)$$

where k is expressed by its real and imaginary components $k=r+js$.

Equation (11) can be expanded into the form

$$\tan(2\beta l\sin\theta_0)=-\tan 2\phi\frac{\sinh k}{\cosh k-1/\cos(2\phi)}. \quad (11a)$$

Equations (12) and (11a) are identical for $s=0$, that is, for real positive values of k. Equation (12) again shows that the direction of minimum radiation is different from the required value unless k equals $-\infty$ (no coupling).

The Distortion of the Original Symmetry Due to Mutual Coupling

Consider now in Fig. 1 the field of antenna A_1 and antenna A_2 produced by the generator G_1 alone. Generator G_2 including feed line F_2 may be replaced by a suitable impedance Z_A connected between the terminals of antenna A_2 and equal to the impedance seen from the antenna A_2 looking into its feed line F_2. From (7), with $E_{A_2}'=0$ and $E_{A_1}'=E_A$,

$$\begin{aligned}E_{A_1}&=E_A/[1-\exp(2k)]\\E_{A_2}&=E_A/[1-\exp(2k)]\exp(k)\end{aligned} \quad (13)$$

the total field at a distant point P is

$$\begin{aligned}E_{P_1}&=\frac{E_A}{1-\exp(2k)}[\exp(j\beta l\sin\theta)\\&\qquad+\exp(k)\exp(-j\beta l\sin\theta)]\\&=E_A\frac{2j\exp(k/2)}{1-\exp(2k)}\sin(\beta l\sin\theta-k/2). \quad (14a)\end{aligned}$$

The same voltage E_A delivered by the generator alone, replacing F_1 and G_1 by an impedance Z_A, instead of G_1 obviously produced a field

$$E_{P_2}=E_A\frac{2j\exp(k/2)}{1-\exp(2k)}\sin(-\beta l\sin\theta-k/2) \quad (14b)$$

from which a symmetry relation follows, with

$$E_{P_1}(\theta)=E_{P_2}(-\theta). \quad (15)$$

This condition is sketched in Fig. 2. Again, the original symmetry condition is represented by the two circles, whereas the present fields are distorted by coupling

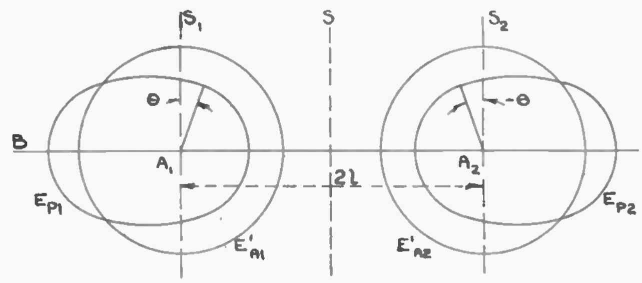

Fig. 2—Distortion of the original symmetry because of mutual coupling.

and represented by the two oval curves, which show mirror symmetry with respect to the plane of symmetry S. The distortion is due to the sine term and the constant $k/2$, in (14). It is evident that the two fields will not compensate in any direction. The disturbing

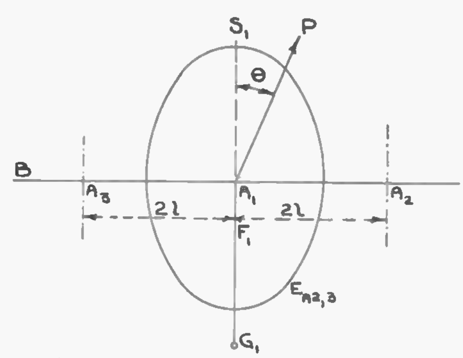

Fig. 3—The original symmetry is restored by a parasitic antenna A_3.

effect of the unexcited antenna can be counterbalanced by an arrangement according to Fig. 3, in which a third parasitic antenna element A_3 is introduced on the baseline B at the same distance $2l$ of A_2 from A_1 but in opposite direction. This "dummy" again is loaded at its terminals by an impedance Z_A and is similar in all respects to antenna A_2. The field of this arrangement obviously is different from the field of antenna A_1 alone, but it necessarily has the symmetry determined by (2) and may have, for instance, the form indicated in Fig. 3. Indeed the currents induced in A_2 and A_3 are in phase and their fields combine to a resultant field of the form

$$E_{A_{2,1}}\cong\exp(k')\cos(\beta l\sin\theta) \quad (16)$$

where k' is a complex constant. This field has the original symmetry, just as the field produced by antenna A_1 alone. If two such triple antenna systems are joined together, a perfect null-shifting directional system is obtained, because (1) and (2) are fulfilled. Consider, for instance, the arrangement of four antennas as shown in Fig. 4, in which the two inner antennas are driven, the two outer antennas being dummies; and

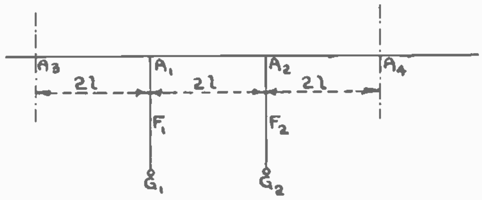

Fig. 4—Improved antenna system. A_3 and A_4 are parasitic elements.

where the distance between two adjacent antennas is the same and equal to $2l$. The first system consists of antenna A_1 plus two dummies A_2 and A_3; the second system consists of antenna A_2 plus two dummies A_1 and A_4. Unfortunately, this is not perfectly true, because A_4 cannot be neglected completely in the first system, nor can A_3 be neglected altogether in the second system. But their influence is small and of the second order because of their twofold distance from the respective driven elements. Thus a considerable improvement in performance over a system without dummies is achieved.

The Infinite Periodic Antenna System

To be exact, the addition of the second system again introduces the pattern asymmetry since antenna A_1 has only one antenna at the left side and two on the right side; while antenna A_2 has two at its left side and only one at its right side.

The same number of antennas on both sides of each driven antenna in the directive system apparently can be obtained only by arranging an infinite number of identical antennas at equal distances on both sides and in line with the two driven center antennas. Thus one arrives at the conception of the infinite periodic antenna array. The direction of zero radiation of an infinite array follows the law of (5).

In practice it is not necessary to extend the array very far from the center. It was found that the addition of only one dummy antenna at each side considerably reduced the maximum directional error (from 8 to about 2 degrees in one special case). The addition of two dummy antennas on each side reduced the error to a magnitude comparable to other errors in the system and has been found sufficient for all practical applications. As expected, the quality of the "null" improves as the error in direction is reduced, and almost perfect zero radiation in the desired direction can be achieved at all frequencies.[2]

The implication in the design of an infinite periodic array is to start with the directional pattern of an infinite number of antennas with one driven antenna in the center, instead of with the pattern of one single antenna isolated in space. If this pattern has the form $E_A(\theta)$, then the pattern of the system is given by

$$E = E_A(\theta) \sin [\beta l \sin \theta - \phi]. \tag{17}$$

As the whole problem was reduced to a problem of symmetry, the result can now be generalized:

1. Each antenna A_n need not be a single antenna, but may consist of a small system by itself, containing for instance one or more reflector elements; or it may consist of one or more antennas arranged in front of a metal shield. An infinite metal shield is indeed equivalent to a number of additional antennas, given by the images of the actual antennas.

2. The two antennas connected to the feed lines need not be adjacent to each other, but one or more dummies may be located between them.

3. Our considerations apply to any kind of antennas and are not restricted to dipoles. A general infinite array, therefore, may be described as follows (Fig. 5). (The letters A refer to identical antennas, which means antennas of the same physical size and shape and looking into the same impedance at their input point. All elements A would have the same radiation patterns and the same electrical characteristics if isolated in free space. The same holds true for the identical antennas B, for the antennas C, and so on.) The periodic system, consists of an infinite number of antenna elements A, B, C, D . . . arranged in space in a periodic recurrent fashion, as indicated in Fig. 5. The row of antennas has to be thought of as continued to the left and to the right ad infinitum.

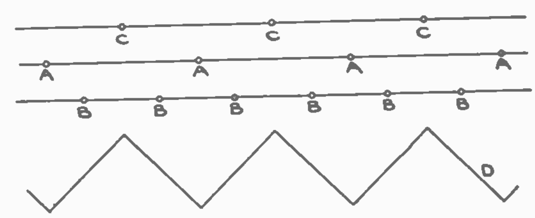

Fig. 5—Infinite periodic antenna system with screen.

Through any particular antenna A a plane S may be passed to make it a plane of symmetry for the whole system. In consequence the radiation pattern of this antenna will be symmetric with respect to S. The planes of symmetry through other antennas A are parallel to S. Any two of the antennas A then can be made the active (driven) antennas of the whole system. In Fig. 5, antennas C could be used as well as active antennas, but not antennas B, as no plane of symmetry for the whole system can be passed through B.

A possible screen D has to have the same conditions of symmetry. That is, the mentioned planes of symmetry have to be planes of symmetry of the shield as well. The images of all antennas produced by the screen then also fulfill the required symmetry conditions.

[2] It is important to note that from the standpoint of directivity no match of the antenna is required at its feed point; and that the results are true only if no coupling exists between feed lines and generators or receivers connected to them.

Theory of Mode Separation in a Coaxial Oscillator*

PETER J. SUTRO†

***Summary*—The problem of separating the first and third modes of oscillation in a standard coaxial oscillator is considered. It is shown that the mode separation (the difference in the settings of one of the two resonant sections for the two modes) increases with the difference between the products of terminating capacitance and characteristic impedance for the two sections. The mode separation is seen to vary quite slowly as a function of frequency.**

Introduction

A COMMON type of high-frequency oscillator uses two sections of coaxial transmission line as resonant circuits. Each of these line sections resonates with the corresponding interelectrode capacitance which terminates one end of the section; the other end is terminated by a shorting plug whose position is adjustable. Fig. 1 illustrates the arrangement. For the sake of simplicity, a parallel-wire line has been drawn rather than a coaxial line; the theory, of course, applies to either.

Fig. 1

One of these sections, here called section (a), may be considered to determine the frequency of oscillation in accordance with the equation

$$\frac{1}{\omega C} = Z_0 \tan \frac{\omega l}{v}, \tag{1}$$

where l is the length of section (a) to the shorting plug, Z_0 is the characteristic impedance of line (a), v is the velocity of propagation in this line, C is the interelectrode capacitance, and ω is the angular frequency at which the section resonates with the terminating capacitance C.

There is a series of angular frequencies which satisfy this equation for a given setting of the shorting plug. These are denoted by ω_1, ω_3, ω_5, etc. Here ω_1 is such that the corresponding angular length of the section $\omega_1 l/v$ is an angle in the first quadrant; it is known, therefore, as the first mode of resonance. Similarly, ω_3 is the third mode, because its value is such that $\omega_3 l/v$ is a third quadrant angle, and so forth.

Section (b) (the other section) may then be considered to determine at which of these possible frequencies the apparatus actually oscillates, in accordance with the equation

$$\frac{1}{\omega C'} = Z_0' \tan \frac{\omega l'}{v'}, \tag{2}$$

where ω is one of the angular frequencies of resonance discussed above, and the prime indicates a quantity for section (b) corresponding to the unprimed quantity of section (a) (i.e., C' is the interelectrode capacitance terminating section (b), Z_0' is the characteristic impedance of line (b), and so on). If (b) is not properly tuned, the oscillator delivers no appreciable power.

Derivation and Formulas

Consider then the first and third modes of resonance resulting from a given setting of the length of section (a). The two frequencies are determined by

$$\frac{1}{\omega_1 C} = Z_0 \tan \frac{\omega_1 l}{v} \qquad \left(0 \leqq \frac{\omega_1 l}{v} \leqq \frac{\pi}{2}\right), \tag{1a}$$

$$\frac{1}{\omega_3 C} = Z_0 \tan \frac{\omega_3 l}{v} \qquad \left(\pi \leqq \frac{\omega_3 l}{v} \leqq 3\frac{\pi}{2}\right). \tag{1b}$$

For the apparatus to oscillate at the angular frequency ω_1, the length of section (b) must be adjusted to a value l_1' such that

$$\frac{1}{\omega_1 C'} = Z_0' \tan \frac{\omega_1 l_1'}{v'} \qquad \left(0 \leqq \frac{\omega_1 l_1'}{v'} \leqq \frac{\pi}{2}\right). \tag{2a}$$

Similarly, if the oscillation is to be at the angular frequency ω_3, the length of section (b) must have the value l_3', given by

$$\frac{1}{\omega_3 C'} = Z_0' \tan \frac{\omega_3 l_3'}{v'} \qquad \left(\pi \leqq \frac{\omega_3 l_3'}{v'} \leqq 3\frac{\pi}{2}\right). \tag{2b}$$

There is, of course, a series of values of l_1' which satisfy (2a). In practice, however, in order to keep the length of the section short, the lowest value is used, such that $\omega_1 l_1'/v'$ is a first quadrant angle, as indicated above. The value of l_3' closest to this lowest value of l_1' is almost always the one such that $\omega_3 l_3'/v'$ is in the third quadrant. These are values considered here.

In order to avoid oscillations of an undesired frequency, l_1' and l_3' must be as different as possible. If l_3' is too close to l_1' it becomes very difficult to separate the two modes of oscillation. The problem, then, is to find the conditions on the line constants and terminating capacitances which make the difference between l_1' and l_3' as large as possible—that is, which maximize $|\Delta l|$, where by definition $\Delta l \equiv l_3' - l_1'$.

It must be remarked that an implicit assumption has been made in the foregoing: that the interelectrode capacitances C and C' do not vary when the mode is shifted. Since the frequency changes by a factor of three or more in going from the first to the third mode, generally this assumption is not strictly true; the equivalent terminating capacitance depends on end

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† Columbia University, New York, N. Y.

effects in the line section, the precise method of loading the oscillator, and other factors which vary with frequency. The change in capacitance resulting from the frequency shift is usually fairly small, however, and although it may introduce some errors in the precise numerical results, it does not affect the qualitative general conclusions. Consequently it is neglected here.

The problem now is to solve (1a) and (1b) for ω_1 and ω_3, whereupon l_1' and l_3' can be found easily from (2a) and (2b). In these equations, unfortunately, the angular frequency appears in the argument of a transcendental function as well as outside the function, and therefore it cannot be found directly. The following procedure, however, leads to a form of the equations for which general curves can be plotted.

Define the following function of the arbitrary variable y:

$$\boxed{\psi(k, y) \equiv \frac{1}{k}\left(\pi + \text{ctn}^{-1} ky - k\text{ctn}^{-1} y\right)}, \qquad (5)$$

maintaining the convention that $\text{ctn}^{-1}y$ and $\text{ctn}^{-1}ky$ are first quadrant angles when y is positive (the only case of interest here). Equations (3) and (4) can then be rewritten in terms of this function:

$$\boxed{\psi(k, \alpha) = 0} \qquad (\alpha \equiv \omega_1 CZ_0), \qquad (3a)$$

$$\boxed{\Delta l = \frac{v'}{\omega_1}\psi(k, \beta)} \qquad (\beta \equiv \omega_1 C'Z_0'), \qquad (4a)$$

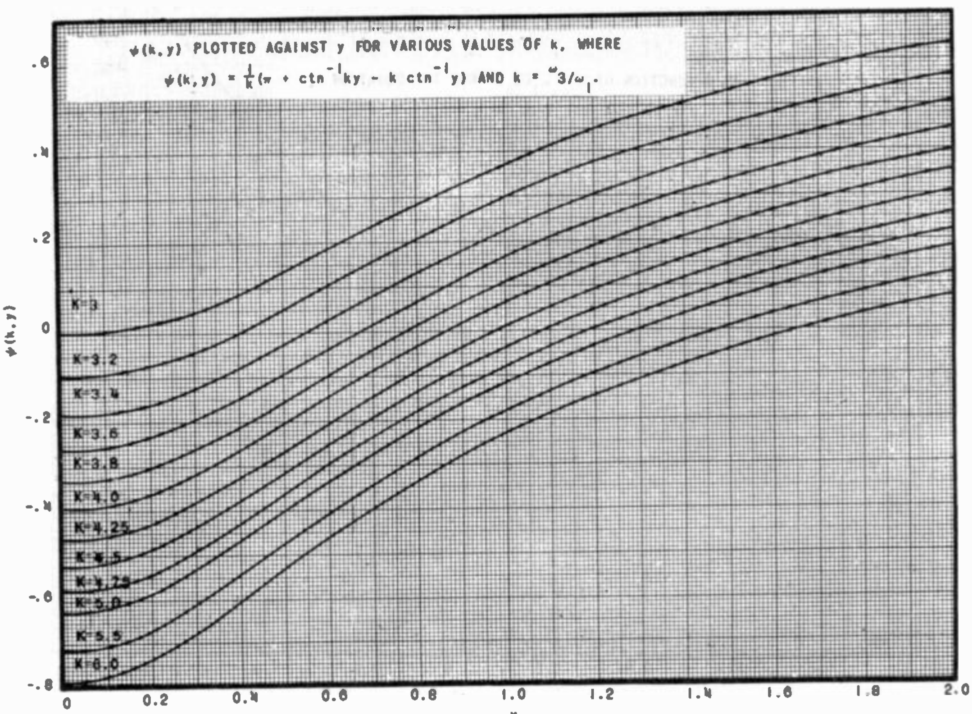

Fig. 2

For the sake of brevity, define:

$$k \equiv \frac{\omega_3}{\omega_1} \quad (\text{thus } \omega_3 = k\omega_1), \qquad \alpha \equiv \omega_1 CZ_0, \qquad \beta \equiv \omega_1 C'Z_0'.$$

Equations (1a) and (1b) then become $\alpha = \text{ctn}\theta_1$ and $k\alpha = \text{ctn}k\theta_1$, where $\theta_1(=\omega_1 l/v)$ is a first quadrant angle and $k\theta_1$ is in the third quadrant. Assume the convention that the inverse trigonometric function of a positive argument is an angle in the first quadrant. These equations can then be rewritten and combined to give $k\text{ctn}^{-1}\alpha = \pi + \text{ctn}^{-1}k\alpha = k\theta_1$, or

$$\pi + \text{ctn}^{-1} k\alpha - k\text{ctn}^{-1} \alpha = 0. \qquad (3)$$

Similarly, (2a) and (2b) can be rewritten to give

$$\pi + \text{ctn}^{-1}k\beta - k\text{ctn}^{-1}\beta = \theta_3' - k\theta_1' = (k\omega_1 l_3'/v') - k(\omega_1 l_1'/v'),$$

or

$$l_3' - l_1' \equiv \Delta l = \frac{v'}{k\omega_1}\left[\pi + \text{ctn}^{-1} k\beta - k\text{ctn}^{-1} \beta\right]. \qquad (4)$$

where $k \equiv \omega_3/\omega_1$, and $\Delta l \equiv l_3' - l_1'$. Equation (3a) is considered as determining k, and equation (4a) as determining Δl from k.

Fig. 2 is a plot of the function $\psi(k, y)$ against y for various values of k. From the intersections of these curves with the line $\psi = 0$, Fig. 3 was plotted as a solution to (3a). This figure shows that (3a) has no solution for k less than 3, since α must be positive. (The solution $k=3$ corresponds to the condition where section (a) is terminated in a zero capacitance—that is, an infinite reactance.)

Discussion and Conclusions

It is clear from Fig. 2 that $\psi(k, y)$ is a monotonically increasing function of y which approaches a finite value as y goes to zero and another finite value as y approaches infinity. Fig. 3 indicates that k is a monotonically increasing function of α, going to the value 3 for $\alpha = 0$ and approaching infinity as α does.

Now since ψ is monotonic and $\psi(k, \alpha)=0$ is the equation determining k, in order to maximize the function $|\psi(k, \beta)|$ (to which $|\Delta l|$ is proportional) it is obviously necessary to make $|\alpha-\beta|$ as large as possible. In other words, one must make CZ_0 as different from $C'Z_0'$ as is practicable.

A brief calculation may illustrate this point. If $Z_0=50$ ohms and $C=4.1$ micromicrofarads at a first mode frequency of 1000 megacycles, then one has $\alpha=(2\pi\times10^9)(4.1\times10^{-12})(50)=0.41\pi=1.3$ (approximately). This gives, from Fig. 3, $k=5$. Now if $C'=2.5$ micromicrofarads and Z_0' is made 82 ohms, one obtains $\beta=1.3=\alpha$. A glance at Fig. 2 shows that $\psi(5, \beta)=0$ for $\beta=1.3$, and therefore that $\Delta l=0$. If Z_0' is made 25 ohms, however, one finds $\beta=0.39$ and consequently $\psi(5, \beta)=-0.48$ in this case. If $v'=3\times10^{10}$ centimeters per second, one has $\Delta l=(-0.48)(3\times10^{10})/(2\pi\times10^9)$ centimeters $=-2.3$ centimeters, a large enough value so that there should be no trouble in keeping the modes separate.

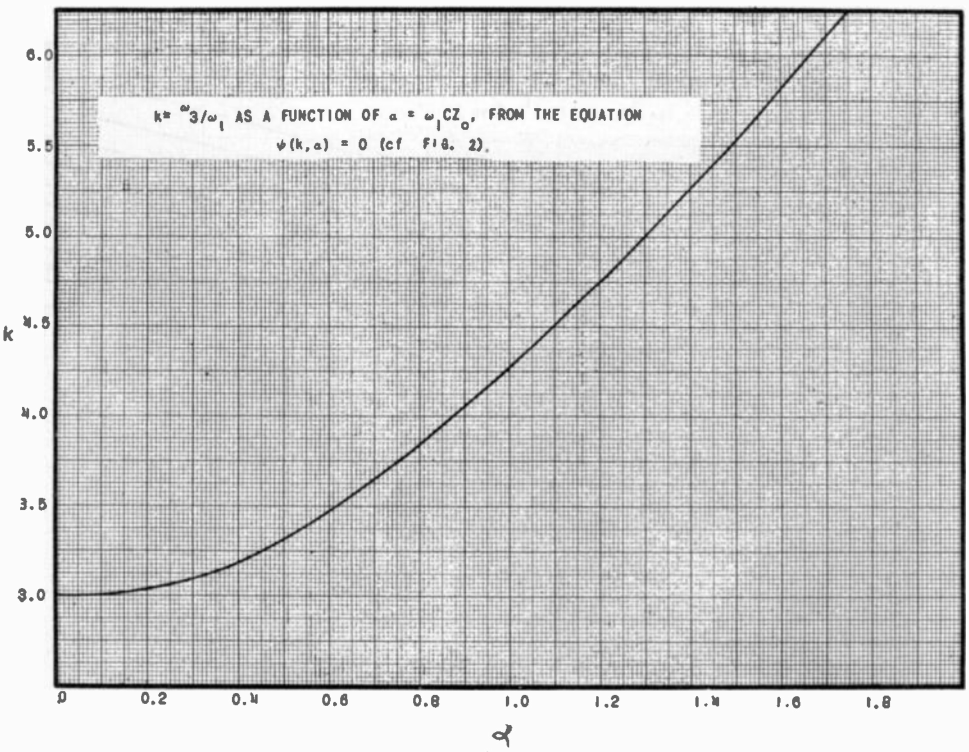

Fig. 3

At first glance it might appear that this solution would require a calculation like the above for every frequency in the range of interest. This is not the case. The definitions show that $\alpha-\beta\equiv\omega_1(CZ_0-C'Z_0')$. The quantity $\mu\equiv CZ_0-C'Z_0'$ is nearly constant with frequency. To a first approximation, the curves of Fig. 2 may be assumed linear and parallel, at least in the region near $\psi=0$. Under this assumption, the value of $\psi(k, \beta)$ is proportional to the difference $\alpha-\beta\equiv\mu\omega_1$, no matter what the values of α and β are; hence ψ/ω_1 is proportional to μ. Equation (4a) then shows that, to a first approximation, Δl is proportional to μ and independent of frequency.

The foregoing argument, of course, is only a rough approximation, but it indicates that the mode separation Δl varies quite slowly with the frequency of the first mode. In almost every case a linear interpolation between the results of two calculations, one at either end of the frequency range to be covered, will be accurate enough for all practical purposes at any intermediate frequency. For maximum mode separation, the chief aim should be to maximize $|\mu|$; that is, to make the quantity $|CZ_0-C'Z_0'|$ as large as is practicable. Whether CZ_0 is larger or smaller than $C'Z_0'$ is generally of little importance, and is usually determined by design and construction considerations; when other criteria are lacking, it can be decided by referring to Figs. 2 and 3.

It should perhaps be remarked that the foregoing is concerned with the values chosen for CZ_0 and $C'Z_0'$ only from the point of view of mode separation. In the design of an actual oscillator, this criterion is only one of many considerations which enter into the selection of values for these quantites; among other important factors which must be considered at the same time are such items as physical size, circuit efficiency, frequency bandwidths, and so forth. Thus, although the mode separation increases directly with the difference in the CZ_0 products for the two coaxial-resonator systems, one is unwilling, in general, to go to extremes in this direction at the expense of other characteristics. As always, a balance must be struck between the various factors, and compromise values selected for the circuit constants on the basis of over-all performance.

Contributors to the Proceedings of the I.R.E.

Richard F. Baum

Richard F. Baum (A'42) was born on August 18, 1911, at Most, Czechoslovakia. He received his E.E. degree in 1935 from the Technische Hochschule in Prague, and a radio engineer's diploma in 1939 from the Ecole Superieure d'Electricité in Paris.

He worked for several years in the field of power applications. From 1940 to 1941 he was a radio operator in the United States Signal Corps. Subsequently he worked as development engineer with the Industrial Instruments, Inc., Jersey City, New Jersey, on the suppression of radio interference in army vehicles. From 1942 to 1945, he was employed as senior engineer at the Federal Telephone and Radio Research Laboratories in New York, N. Y., and was engaged in the development of direction-finding systems. Since July, 1945, he has been a member of the microwave communication department at the Raytheon Manufacturing Company, Inc., in Waltham, Massachusetts.

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M. J. O. Strutt (SM'46) was born at Soerakarta, Java, in 1903. From 1921 to 1927 he studied at the University of Munich; the Institute of Technology at Munich; and the Institute of Technology at Delft, Holland. He was graduated from Munich in 1924, and received, from Delft, his degree in electrical engineering in 1926, and the degree of Doctor of Technical Science, in 1927. During 1926 and 1927, Dr. Strutt served also as a member of the staff at Delft and as a patent engineer.

In 1927 he joined the Philips Lamp and Radio Company, Ltd., Eindhoven, Holland, participating in research on electroacoustics from 1930 to 1933. Later he was in charge of the research group on reception and ultra-high-frequency tubes. In 1945 Dr. Strutt became an electronics consultant.

He is a member of the Royal Institute of Engineers at the Hague, the Dutch Radio Society, the Dutch Mathematical Society, and the Society for the Advancement of Physics and Medicine at Amsterdam.

M. J. O. Strutt

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H. W. Wells

H. W. Wells (A'36–M'36–SM'43) was born on January 13, 1907, at Washington, D. C. He received the B.S. degree in electrical engineering in 1928, and the E.E. degree in 1937 from the University of Maryland. Between 1928 and 1932, he was associated with the Westinghouse Electric and Manufacturing Company, the All-American Mohawk Expedition to Borneo, Heintz and Kaufman, and the Army Air Forces.

Mr. Wells has been a member of the scientific staff of the Department of Terrestrial Magnetism, Carnegie Institution of Washington, since 1932. His investigations both here and abroad have contributed materially to knowledge of the ionosphere, radio wave propagation, and related geophysical subjects.

He is a member of the Committee on Wave Propagation and Utilization of the Institute of Radio Engineers. His professional affiliations include the Washington Academy of Sciences, American Geophysical Union, and the Philosophical Society of Washington.

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For a biography and photograph of Haraden Pratt, see the October, 1945, issue of the Proceedings of the I.R.E. A biography and photograph of Arthur Van Dyck appeared in the January, 1943, issue of the Proceedings.

Peter J. Sutro

Peter J. Sutro was born on June 20, 1921, at New York City. He received the B.A. degree in physics from Harvard University in 1942. During the war, from 1942 to 1946, he was working on radar countermeasures as a research associate at the Radio Research Laboratory of Harvard University, which was operated under a contract with the Office of Scientific Research and Development. He has now resumed his studies in the physics department of Columbia University. He is a member of the American Physical Society.

❖

Leland E. Thompson (A'35–SM'44) was born at Creighton, Nebraska, on September 18, 1905. He received the B.S. degree in electrical engineering from the University of South Dakota in 1929. From 1929 to 1930 he was employed in the radio-engineering department of the General Electric Company. Since 1930, Mr. Thompson has been associated with the Radio Corporation of America, RCA Victor Division, Camden New Jersey.

Leland E. Thompson

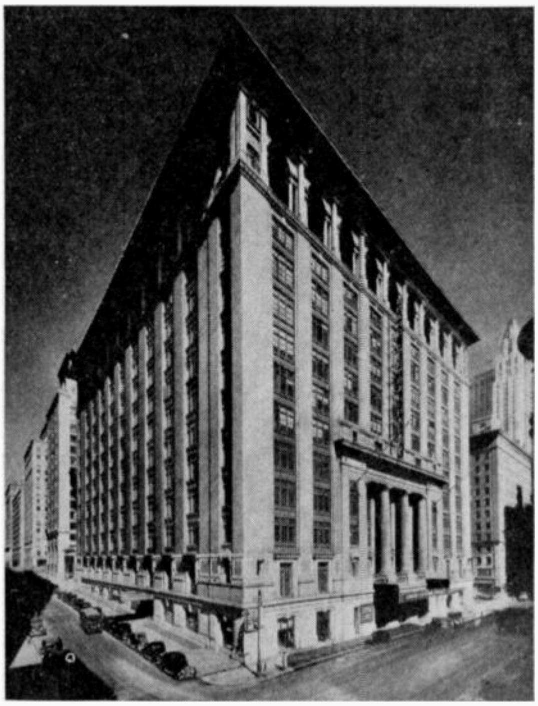
National I. R. E. Convention 1947

It is estimated that many thousands of members of The Institute of Radio Engineers and professional engineers will gather in New York City for the Institute's five-day 1947 National Convention to be held on March 3 to 7.

The convention will publicize recent developments in the field of electronics, to the end that society will benefit by the industry's research. Along with engineering progress, an understanding of important current developments should be offered to the public. With that, a social responsibility will have been met. The 1947 Convention's theme was voted to be "Electronics at Peace!"

Scheduled for sessions lasting four days are three major features—a Symposium of I.R.E. Technical Committees, including technical papers to be read on the latest developments in the field of electronics—commercial exhibits at the Grand Central Palace building at 46th and Lexington Avenue—and the Annual Banquet set for Wednesday evening.

The technical meetings and all social functions will be held at the Hotel Commodore, Lexington Avenue and 42nd Street. All technical papers will be presented for the first time and none will have been published before in any form. Technical sessions will start on Monday morning, March 3.



GRAND CENTRAL PALACE BUILDING WHERE EXHIBITION WILL BE HELD

Approximately one hundred and eighty manufacturers are expected to exhibit the concrete results of their engineering research from one o'clock Monday afternoon until Thursday evening at ten. The exhibits will be open each night until ten, except for Wednesday when the Banquet will be held at the Hotel Commodore. On Wednesday the Grand Central Palace will close at six. The exhibit of electronic equipment, parts, and materials will provide a meeting ground for visiting engineers desiring to discuss their mutual problems.

Thirty-six lectures, as well as demonstrations with sound equipment, a display of military radio devices, and a historical tube exhibit, will supplement the standard exhibits.

The Annual Banquet has been set for Wednesday night, on which occasion a nationally prominent figure will address those assembled. In addition to a program of entertainment, there will be scheduled the presentations of the Institute Medal of Honor and the Morris Liebmann Memorial Prize, both awarded for distinguished service in the field of radio communications. The names of the new Fellows elected into the Institute will be announced and the President of the I.R.E. will address the gathering.

Monday afternoon, the press is scheduled for a luncheon and a visit to the Grand Central Palace. There will also be a social gathering for those desiring to attend on Monday night.

Under the guiding hand of Mrs. F. B. Llewellyn, a special program is planned for the ladies of the Convention. All the plans have not been set, but it is expected that a tea will be held for the ladies at the new Institute building on Tuesday, in addition to other activities.

Officials and members of the General Committee for the Convention include: Chairman, James E. Shepherd; Vice-Chairman, Philip F. Siling; Secretary, Edna Harding; Committeemen, George W. Bailey, Austin Bailey, Stuart L. Bailey, B. E. Shackelford, Edward J. Content, Elizabeth Lehmann, and J. R. Poppele.

Subcommittee chairmen in charge of the various activities are: Finance, F. R. Lack; Hospitality Registration, R. D. Campbell; Hospitality, E. Finley Carter; Women's Activities, Mrs. F. B. Llewellyn; Technical Program, Ernst Weber; Facilities, R. D. Chipp and John G. Preston; Printed Program, J. W. McRae; I.R.E. PROCEEDINGS, Helen M. Stote; Publicity, Virgil M. Graham; Exhibit Requirements, Dorman D. Israel; Exhibit Manager, William C. Copp; Hotel Arrangements, H. F. Scarr; Banquet, George McElrath; President's Luncheon, A. B. Chamberlain; Cocktail Party, Edmour F. Giguere; Acoustic Requirements, Leo L. Beranek; and Section Activities, W. O. Swinyard.

The 1947 National I.R.E. Convention may well prove to be one of the significant gatherings in the history of the Institute. For there will be assembled on that occasion the products of the war years . . . of this age of the electron . . . and now of the first year of peace.

Institute News and Radio Notes

Board of Directors

October 2, 1946

Report of the President. President Llewellyn gave an interesting and informative talk on his trip to the Sections from Montreal to the Pacific Coast and Texas at the October 2 meeting of the Board of Directors.

Proposed Bylaw, Section 55

The following is the modification of Bylaw, Sec. 55 as approved by the Board of Directors at the October 2, 1946, meeting.

"Sec. 55. The Executive Secretary is authorized to accept orders for annual subscriptions to, or individual copies of the PROCEEDINGS at the following rates, including postage:

	United States and Canada	Other Countries
Annual Subscriptions		
Individual Nonmembers	$12.00	$13.00
Public Libraries	9.00	10.00
Colleges	9.00	10.00
Subscription Agencies	9.00	10.00
Institute Members, Additional Subscriptions	7.50	8.50
Individual Copies		
Individual Nonmembers	1.50	1.60
Public Libraries	1.10	1.20
Colleges	1.10	1.20
Subscription Agencies	1.10	1.20
Institute Members, Additional Copies	1.00	1.10

The motion for adoption of the proposed Bylaw Section 55 should include the provision for it to become effective January 1, 1947."

Nomination Petition for Director

As a result of a properly signed petition, in accordance with the constitutionally provided procedure, the name of William F. Diehl was added to the list of nominees for Director for 1947–1949.

Canadian Affairs

At the September 4, 1946, meeting of the Board of Directors, R. A. Hackbusch called attention to the fact that the Toronto Section should sponsor the Winnipeg subsection and also that Canada, as one entity, should be a Region.

Buenos Aires Section

In reply to a request of the Buenos Aires Section, the Board of Directors at its September 4, 1946, meeting authorized that the section be permitted to manufacture its own emblems according to all Institute specifications, with the exception that silver may not be substituted for gold.

President Llewellyn Visits Montreal Section

At the September 3, 1946, meeting of the Executive Committee, G. W. Bailey read a letter from President Llewellyn. This letter was written after Dr. Llewellyn's visit to the Montreal Section and in it he mentioned comments of members of the Section on various policies of the Institute.

Tellers Committee Reports

At the August 6, 1946, meeting of the Executive Committee, the reports of the Tellers Committee tabulating the results of the March 15, 1946, Constitutional Amendment Ballot and the May 8, 1946, Constitutional Amendment Ballot on the Regional-Representation Plan, were unanimously approved. The amendments stand adopted by the membership.

> Readers of the PROCEEDINGS OF THE I.R.E. will be interested to learn that it is not planned to publish the WAVES AND ELECTRONS Section as a separate periodical but rather, for the present, to include it solely as a section of the PROCEEDINGS OF THE I.R.E.
> —The Editor.

Appointment of I.R.E. Assistant to the Executive Secretary

Elwood K. Gannett, newly appointed assistant to the executive secretary, began his association with the Institute on August 26, 1946.

Buenos Aires Spring Meeting

On November 11 to 14, 1946, the Buenos Aires Section will hold a Spring Meeting. The Executive Committee has approved their plans and has requested that a full statement be submitted of the activities of the meeting for possible publication in the PROCEEDINGS OF THE I.R.E. AND WAVES AND ELECTRONS.

I.R.E. Booths

The Institute of Radio Engineers had booths at the National Electronics and Television Exhibits, held at Grand Central Palace, New York City, October 10 and 11, 1946, and at the Rochester Fall Meeting, held at the Hotel Sheraton, Rochester, New York, November 11, 12, and 13, 1946. These booths were under the supervision of William C. Copp, Advertising Manager. The layout and printed material for distribution were submitted to the Executive Secretary for approval.

I.R.E. Accepts Membership in Army Signal Association

The Institute of Radio Engineers has accepted the invitation of the Army Signal Association to become an honorary group member of the Association.

Engineering Instruction in South Africa

The University of Witwatersrand, located in Johannesburg, South Africa, has been added to the approved list of schools of recognized standing.

Canadian Radio Engineers Council

The London, Toronto, Ottawa, and Montreal Sections were represented at the June 25, 1946, meeting of the Canadian Institute of Radio Engineers Council which was held in Toronto, Ontario, Canada. At this meeting the following actions were taken:

The new Papers Committee was authorized to plan for "Tour Speakers" and urged to keep the Sections advised regarding these and the activities of Headquarters' "Speakers Bureau."

The report of the Council Education Committee, presenting the following summary of its activities since formation in 1942, was adopted:

> A Student Night has been established and university students have been invited to participate. The best papers were selected from contributions and presented at a regular I.R.E. Meeting held near the end of the year. Prizes of $15, $10, and a year's student membership were given.
>
> The Committee made a study of the needs of the radio engineering community with respect to advanced radio educational requirements. The results proved helpful to McGill University in planning its postgraduate evening courses in communications. A similar study is now being made for evening undergraduate studies.
>
> A seminar group has been formed whose meetings review and discuss important papers published in the PROCEEDINGS OF THE I.R.E. AND WAVES AND ELECTRONS.
>
> As a result of the Committee's efforts to stimulate interest in progressive ideas in education, Dr. Guillemin and Dr. Everitt have given addresses on the subject to the Montreal Section.
>
> The Committee is circulating a questionnaire on the careers of communications and electronics engineers, in an attempt to discover the field where they are in greatest demand, as well as to determine what part of their formal education has been most useful to them. The results on a study of the replies will be made available to students and others who may find the information helpful,

and will be offered for inclusion in a booklet being prepared by the *Canadian Journal of Professional Engineers and Scientists.*

Some information regarding undergraduate studies which might lead to a degree of Bachelor of Communication Engineering has been prepared.

The Chairman of the Canadian Council of Professional Engineers and Scientists reported that there are now eleven national engineering and scientific organizations associated with it. This Council has presented briefs to the proper persons regarding improvement of labor regulations and salaries of engineers and scientists. The Chairman also reported that The Institute of Radio Engineers, as well as the Canadian I.R.E. Council, is represented on the Canadian Council of Engineers and Scientists. At the conclusion of this report it was voted that the Canadian I.R.E. Council continue to support the C.C.P.S. for 1946–1947.

The Chairman reported that collective bargaining had gained headway, with both the Quebec and Ontario Federations of Professional Employees showing a growing membership and increase in units making application for certification. Interest in the bargaining federations was expressed by the Council Members and an effort will be made to have the Section Chairmen placed on the mailing list for Federation News Sheets.

Mr. Hackbusch reported that the Headquarters Board of Directors always was sympathetic toward the Council and was watching its development with interest since the proposed Regional plan had been based very largely on the Council's setup.

Dr. F. S. Howes was re-elected chairman, and Mr. H. S. Dawson was elected vice-chairman of the Council for 1946–1947 Session.

The Standing Committees (Professional Status, Charter, Papers, and Education) will be continued, and a new one will be set up to deal with Membership and Admission Standards. One of the duties of this Committee will be to study and report on what constitutes a "College of Recognized Standing" for membership purposes.

The Toronto Section will prepare a report on its experience in sponsoring the Winnipeg subsection for submission to Headquarters, and will make plans for sponsoring a subsection in Vancouver. Until a Subsections Manual can be prepared, subsections are advised to operate on the Sections Manual. Since there will be no Members at Large under the new Regional Plan, it was proposed that Toronto will sponsor members in the West until sections are established in Winnipeg and Vancouver. [These subsections have since been established.—The Editor.]

It is planned that all Sections hold their Annual Meeting not later than May 15 each year, and that all Sections, the Council Secretary, and Headquarters be notified of the new slate of officers immediately. With a view to maintaining the interest of past chairmen, it was suggested that a "Past Chairman's Committee" be set up in each section, this group to be called upon to advise the local executive, and that representatives on Headquarters Committees could be drawn from it.

David Sarnoff Receiving the "Man of Science" Award

Man of Science Award

The "Man of Science" award, offered by the magazine *Science Illustrated*, has been awarded to Brigadier General David Sarnoff (A'12–M'14–F'17). The announcement was made by James McGraw, Jr., president of the McGraw-Hill Company, publisher of the above magazine. The award, in the form of a gold medal and scroll, was given to General Sarnoff on September 30, 1946. It is presented to men who have "by their exceptional talents used science for the advancement of industry and culture." In particular, the award to General Sarnoff was based on his contributions in the upbuilding of the radio industry, his vision and imagination in developing research as a basic element in the progress of his company, and his unusual foresight in analyzing, at each stage, the long-term prospects of various branches of radio. The award scroll also states that he is a leader in the educational and cultural uses of radio and has endeavored throughout to maintain radio on a high level of service.

Engineering Societies Council

Organization of the Engineering Societies Council of New York, comprising delegates from the local chapters of engineering, scientific, and technical societies was recently completed. The Council is intended to enable the engineering profession to produce a better co-ordinated program in Greater New York in the public interest as well as that of the members of the participating organizations. It is the outgrowth of the Engineering Societies Committee on War Production, through whose efforts, at the request of the War Production Board, several successful clinics on technical problems were held during the war. The purposes of the new Council as outlined in detail in the constitution which has been adopted are as follows:

To provide a medium for co-operative action by the member societies on matters of mutual interest which are beyond the scope of the individual organization or which can be performed better by co-operative action.

To encourage interest and participation in public affairs which are scientific or technical in scope.

To cultivate greater appreciation by the public of the part which engineering, science, and technology contribute to human welfare.

To provide a means of more effective public service by the member societies of the Council.

To promote greater unification of the engineering profession and co-operate in a general program for the enhancement of the professional status of the engineer.

To promote co-ordination and integration of the inter-organization activities of the member societies.

To publish information of interest to the member societies.

To co-operate with organizations having similar objectives in other communities.

The names of the officers elected and the societies they represent are:

Chairman—H. C. R. Carlson, American Society of Mechanical Engineers.

Vice-Chairman—H. P. Wall, American Society of Safety Engineers.

Secretary—M. P. Davis, American Society for Testing Materials.

Treasurer—H. F. Dart, Institute of Radio Engineers.

Directors—O. B. J. Frazer, American Institute of Mining and Metallurgical

Engineers; E. J. Lyons, American Institute of Chemical Engineers; W. F. O'Connor, American Chemical Society; C. S. Purnell, American Institute of Electrical Engineers; H. J. Ryan, American Society of Heating and Ventilating Engineers; and E. M. Sherwood, American Society for Metals.

The local chapters of other societies represented are:

American Society of Tool Engineers, American Welding Society, Illuminating Engineering Society, and the Society of Motion Picture Engineers.

I.R.E. delegates to the council are: H. F. Dart (A'20–M'26–SM'43), C. R. Keith (A'44), J. D. Schiller (A'45), J. E. Shepherd (A'36–SM'44), and E. M. Sherwood (A'37). J. L. Callahan (A'21–M'31–SM'43), M. D. Hooven (A'26), and W. A. Howard (A'44) are alternates.

HARRY F. DART

NOTICE

In the review of the book, "Design of Crystal Vibrating Systems," by William J. Fry, John M. Taylor, and Bertha W. Henvis, appearing on page 770 of the October, 1946, issue of the PROCEEDINGS OF THE I.R.E. AND WAVES AND ELECTRONS, it was stated that copies are obtainable free upon request to the Naval Research Laboratory, Office of Research and Inventions, Sound Division.

We are informed by the Naval Research Laboratory that the requests received for this book as a consequence of this notice are so numerous that they far outnumber the limited quantity originally released for public distributi . As a result, only requests from libraries are being honored, and it may not be possible to fill all of these. However, arrangements have been made for release of the book to the Office of Technical Services, Department of Commerce, Washington 25, D. C., which will supply photostat copies for $12.00 per copy and microfilm copies for $2.00 per copy. Orders should carry the identifying number PB No. 22410 and should be accompanied by a check payable to the Treasurer of the United States. Copies will be mailed about five weeks after receipt of the order.

ARMY SIGNAL ASSOCIATION

Radar sets used during World War II will not constitute a satisfactory defense against guided missiles, according to Wilbur C. Brown (M'45), radio engineer in the Office of the Director of Engineering, Signal Corps Engineering Laboratories. Speaking before members of the Army Signal Association at Fort Monmouth, N. J., Mr. Brown told of the Signal Corps phase of the guided-missile program now undergoing continuing studies by the Army, Navy, industrial concerns, and university laboratories.

According to Mr. Brown, the Signal Corps is actively concerned with studies leading to means for warning and detection of guided missiles, including the location of launching bases; tracking the missiles in flight; developing of electronic countermeasures which will be effective against the offensive weapons; and investigating meteorological conditions in the upper atmosphere. The Signal Corps has also been assigned the responsibility for co-ordination of all communication systems to, from, and at the White Sands, N. M., area by the Ordnance Department, which is in nominal charge of the joint project. A radioteletype system is in operation from White Sands to Coles Signal Laboratory, Red Bank, N. J.

Mr. Brown revealed that the Signal Corps was co-operating closely with the Army Air Forces in the radar-warning aspects of the project, the existing methods for projectile flight plotting having proved unsatisfactory for guided missiles because of the speeds encountered. Studies are also being made of the frequencies best suited to track guided missiles of the size, shape, and speed of the so-called "V-2" type currently being tested.

Dr. Harold A. Zahl (SM'46), assistant director of engineering, Signal Corps Engineering Laboratories, reporting his experiences as Signal Corps observer at Operation Crossroads, stated that damage to Signal Corps equipment on ships in the target area ranged from complete to negligible. While results of the first test are yet to be evaluated, it was evident that redesign of wartime Signal Corps equipments, which included such items as the radar equipment SCR-584 and the vehicular radio set SCR-399, would be influenced by the results of the Bikini tests. Such redesign, he intimated, would involve protection against damage from explosion as well as shielding against radioactivity. Dr. Zahl, who returned to the United States immediately following the second test, or Test Baker, reported that the radioactivity was still too high when he left to permit any significant evaluation of the amount or type of damage resulting from the underwater blast. The extent of radioactivity in the various areas was broadcast by radio transmitters connected to Geiger counters and ionization chambers. Signal Corps personnel assisted in the construction of this equipment.

David Sarnoff (A'12–M'14–F'17), president of Radio Corporation of America, is national president of the Army Signal Association, for which one chapter has already been organized and others proposed for Fort Monmouth, Chicago, and Hollywood.

Minutes of Technical Committee Meetings

ANTENNAS

Date..............October 7, 1946
Place.............McGraw-Hill Building, New York City
Chairman.........P. S. Carter

Present

P. S. Carter, *Chairman*

Harry Diamond	D. C. Ports
J. H. Duttera	M. W. Scheldorf
R. T. Holtz (for J. E. Young)	S. A. Schelkunoff
	J. C. Schelleng
R. B. Jacques	George Sinclair
C. H. Jones	P. H. Smith
W. E. Kock	J. W. Wright

Work was continued on definitions as submitted by various sub-committees. It was decided that no action should be taken on suggestions for revision of the 1939 I.R.E. definitions of antenna terms, since these terms apply to systems rather than antennas. This led to the question of whether or not there should be a Systems Committee. It was agreed that the subject of Methods of Testing would be on the agenda of the next meeting. The next meeting will be held in the Conference Room, Ordinance Lab., Bureau of Standards, Washington, D. C., on Monday, November 4, 1946.

ELECTROACOUSTICS

Date.............September 20, 1946
Place.............McGraw-Hill Building, New York City
Chairman.........Eginhard Dietze

Present

Eginhard Dietze, *Chairman*

P. N. Arnold	A. C. Keller
S. J. Begun	G. M. Nixon
R. H. Bolt	Benjamin Olney
R. K. Cook	R. A. Schlegel
J. E. Dickert	E. S. Seeley, Secretary
M. J. Di Toro	

Absent

B. B. Bauer	H. S. Knowles
F. L. Hopper	H. F. Olson
H. H. Scott	

The purpose of the meeting was to consider the definitions already submitted in order to produce a second draft of proposed definitions for further consideration. It was agreed that the objective of the committee will be to complete a dictionary presenting useful electroacoustic definitions. Standards and methods of calibration may be considered after the attainment of this immediate objective.

RADIO TRANSMITTERS

Date.............July 9, 1946
Place.............McGraw-Hill Building, New York City
Chairman.........E. A. Laport

Present

M. R. Briggs	J. B. Knox
Cledo Brunetti	E. A. Laport
H. R. Butler	C. H. Meyer
Harry Diamond	R. L. Robbins
R. B. Jacques	Robert Serrell
I. R. Weir	

The greater portion of the meeting was spent in going through the list of collated definitions to decide which ones were to be defined by this committee. The committee also found that it would be unable to get approval from JAN for release of tentative specifications on definitions for use with transmitters.

RESEARCH

Date..............July 10, 1946
Place.............McGraw-Hill Building, New York 18, N. Y.
Chairman.........F. E. Terman

Present

W. L. Barrow	R. B. Jacques
R. M. Bowie	F. E. Terman
E. W. Engstrom	Julius Weinberger
H. T. Friis	L. C. Van Atta

The committee discussed furthering the scientific training of engineering students, possibly through the I.R.E. Education Committee. To aid in the co-ordination and direction of research, it was agreed that various I.R.E. technical committees might sponsor conferences of a nation-wide scope in specific fields of endeavor. It was further agreed that the committee should encourage publication of basic research papers in the PROCEEDINGS through the Papers Procurement Committee. It was also thought that, periodically articles of an editorial nature might appear dealing with the general trend in the research field. It was thought, too, that a survey of all existing research facilities should be made. It was agreed that the subject of publicizing the research achievements of the engineer should be kept on the agenda for future meetings.

STANDARDS

Date..............August 28, 1946
Place.............McGraw-Hill Building, New York City
Chairman.........R. F. Guy

Present

R. F. Guy, *Chairman*

W. F. Bailey	E. K. Gannett (Ass't Sec'y I.R.E.)
M. W. Baldwin	
R. S. Burnap	L. B. Headrick
P. S. Carter	L. C. F. Horle
A. B. Chamberlain	R. B. Jacques (Tech. Sec'y I.R.E.)
M. G. Crosby	
Eginhard Dietze	E. W. Schafer
Elsie Fisher, Secretary	H. M. Turner
	H. A. Wheeler

R. M. Wilmotte

The *Standards on Methods of Testing Frequency-Modulation Broadcast Receivers (Between 88 and 108 Megacycles)* was examined and minor revisions were made. Discussion was entertained on the following: expressing input signals in terms of input voltage or available power, with the question referred to the Receivers Committee; the terms root-sum-square and root-mean-square and the terms quadratic sum and quadratic mean, with the question referred to the ASA; test methods for effects of downward modulation, for sets with built-in antennas, for effects of volume-control settings, and for inaccurate-tuning distortion, with the recommendation that these items be con-

SECTIONS

Chairman		Secretary
	ATLANTA December 20	M. S. Alexander 2289 Memorial Dr., S.E. Atlanta, Ga.
H. L. Spencer Associated Consultants 18 E. Lexington Baltimore 2, Md.	BALTIMORE	G. P. Houston, 3rd 3000 Manhattan Ave. Baltimore 15, Md.
Glenn Browning Browning Laboratories 750 Main St. Winchester, Mass	BOSTON	A. G. Bousquet General Radio Co. 275 Massachusetts Ave. Cambridge 39, Mass.
I. C. Grant San Martin 379 Buenos Aires, Argentina	BUENOS AIRES	Raymond Hastings San Martin 379 Buenos Aires, Argentina
H. W. Staderman 264 Loring Ave. Buffalo, N. Y.	BUFFALO-NIAGARA December 18	J. F. Myers Colonial Radio Corp. 1280 Main St. Buffalo 9, N. Y.
T. A. Hunter Collins Radio Co. 855—35 St., N.E. Cedar Rapids, Iowa	CEDAR RAPIDS	R. S. Conrad Collins Radio Co. 855—35 St., N.E. Cedar Rapids, Iowa
A. W. Graf 135 S. La Salle St. Chicago 3, Ill.	CHICAGO December 20	D. G. Haines Hytron Radio and Electronic Corp. 4000 W. North Ave. Chicago 39, Ill.
J. D. Reid Box 67 Cincinnati 31, Ohio	CINCINNATI December 17	P. J. Konkle 5524 Hamilton Ave. Cincinnati 24, Ohio
H. C. Williams 2636 Milton Rd. University Heights Cleveland 21, Ohio	CLEVELAND December 26	A. J. Kres 16911 Valleyview Ave. Cleveland 11, Ohio
E. M. Boone Ohio State University Columbus, Ohio	COLUMBUS January 10	C. J. Emmons 158 E. Como Ave. Columbus 2, Ohio
Dale Pollack 352 Pequot Ave. New London, Conn	CONNECTICUT VALLEY December 19	R. F. Blackburn 62 Salem Rd. Manchester, Conn.
R. M. Flynn KRLD Dallas 1, Texas	DALLAS-FT. WORTH	J. G. Rountree 4333 Southwestern Blvd. Dallas 5, Texas
J. E. Keto Aircraft Radio Laboratory Wright Field Dayton, Ohio	DAYTON December 19	Joseph General 411 E. Bruce Ave. Dayton 5, Ohio
H. E. Kranz International Detrola Corp. 1501 Beard Ave. Detroit 9, Mich.	DETROIT December 20	A. Friedenthal 5396 Oregon Detroit 4, Mich.
N. L. Kiser Sylvania Electric Products, Inc. Emporium, Pa.	EMPORIUM	D. J. Knowles Sylvania Electric Products, Inc. Emporium, Pa.
E. M. Dupree 1702 Main Houston, Texas	HOUSTON	L. G. Cowles Box 425 Bellaire, Texas
H. I. Metz Civil Aeronautics Authority Experimental Station Indianapolis, Ind.	INDIANAPOLIS	M. G. Beier 3930 Guilford Ave. Indianapolis 5, Ind.
R. N. White 4800 Jefferson St. Kansas City, Mo.	KANSAS CITY	Mrs. G. L. Curtis 6003 El Monte Mission, Kansas
J. Bach Sparton of Canada. Ltd. London, Ont., Canada	LONDON, ONTARIO	B. L. Foster Sparton of Canada, Ltd. London, Ont., Canada
Frederick Ireland 950 N. Highland Ave. Hollywood 38, Calif.	LOS ANGELES December 17	Walter Kenworth 1427 Lafayette St. San Gabriel, Calif.

Chairman		Secretary
L. W. Butler 3019 N. 90 St. Milwaukee 13, Wis.	MILWAUKEE	E. T. Sherwood 9157 N. Tennyson Dr. Milwaukee, Wis.
J. C. R. Punchard Northern Electric Co. 1261 Shearer St. Montreal 22, Que., Canada	MONTREAL, QUEBEC January 8	E. S. Watters Canadian Broadcasting Corp. 1440 St. Catherine St., W. Montreal 25, Que., Canada
J. T. Cimorelli RCA Victor Division 415 S. Fifth St. Harrison, N. J.	NEW YORK January 8	J. R. Ragazzini Columbia University New York 27, N. Y.
L. R. Quarles University of Virginia Charlottesville, Va.	NORTH CAROLINA-VIRGINIA	J. T. Orth 4101 Fort Ave. Lynchburg, Va.
D. W. R. McKinley 211 Cobourg St. Ottawa, Canada	OTTAWA, ONTARIO December 19	W. A. Caton 132 Faraday St. Ottawa, Canada
Samuel Gubin 4417 Pine St. Philadelphia 4, Pa.	PHILADELPHIA January 2	A. N. Curtiss RCA Victor Division Bldg. 8–9 Camden, N. J.
W. E. Shoupp 911 S. Braddock Ave. Wilkinsburg, Pa.	PITTSBURGH January 13	C. W. Gilbert 52 Hathaway Ct. Pittsburgh 21, Pa.
C. W. Lund Rt. 4, Box 858 Portland, Ore.	PORTLAND	L. C. White 3236 N.E. 63 Ave. Portland 13, Ore.
A. E. Newlon Stromberg-Carlson Co. Rochester 3, N. Y.	ROCHESTER December 19	K. J. Gardner 111 East Ave. Rochester 4, N. Y.
S. H. Van Wambeck Washington University St. Louis 5, Mo.	ST. LOUIS	N. J. Zehr 1538 Bradford Ave St. Louis 14, Mo.
David Kalbfell 941 Rosecrans Blvd. San Diego 6, Calif.	SAN DIEGO January 7	Clyde Tirrell U. S. Navy Electronics Laboratory San Diego 52, Calif.
R. V. Howard Mark Hopkins Hotel San Francisco, Calif.	SAN FRANCISCO	Lester Reukema 2319 Oregon St. Berkeley, Calif.
E. H. Smith 823 E. 78 St. Seattle 5, Wash	SEATTLE January 9	W. R. Hill University of Washington Seattle 5, Wash.
H. S. Dawson Canadian Association of Broadcasters 80 Richmond St., W. Toronto, Ont., Canada	TORONTO, ONTARIO	C. J. Bridgland Canadian National Telegraph 347 Bay St. Toronto, Ont., Canada
M. E. Knox 43—44 Ave., S. Minneapolis, Minn.	TWIN CITIES	Paul Thompson 4602 S. Nicollet Minneapolis, Minn.
F. W. Albertson Room 1111, Munsey Bldg. Washington 4, D. C.	WASHINGTON January 13	G. P. Adair Federal Communications Commission Washington 4, D. C.
W. C. Freeman, Jr. 2018 Reed St. Williamsport 39, Pa.	WILLIAMSPORT January 8	S. R. Bennett Sylvania Electric Products, Inc. Plant No. 1 Williamsport, Pa.

SUBSECTIONS

K. G. Jansky Bell Telephone Laboratories, Inc. Box 107 Red Bank, N. J.	MONMOUTH (New York Subsection)	Lloyd Hunt Bell Telephone Laboratories, Inc. Box 107 Deal, N. J.
C. W. Mueller RCA Laboratories Princeton, N. J.	PRINCETON (Philadelphia Subsection)	A. V. Bedford RCA Laboratories Princeton, N. J.
H. E. Ellithorn 417 Parkovash Ave. South Bend 17, Ind.	SOUTH BEND (Chicago Subsection) December 19	J. E. Willson WHOT St. Joseph and Monroe Sts. South Bend, Ind.
W. A. Cole 323 Broadway Ave. Winnipeg, Manit., Canada	WINNIPEG (Toronto Subsection)	C. E. Trembley Canadian Marconi Co. Main Street Winnipeg, Manit., Canada

sidered for future revision of this report. The reports on *Cathode-Ray and Television Tube Classifications and Definitions*, and *Methods of Testing Vacuum Tubes* were approved with minor revisions. The report on *Television Definitions* was partially approved, as time did not allow the completion of work on criticized definitions. A meeting of all technical committees at the National Convention was proposed and found very desirable.

CHICAGO SECTION APPOINTMENTS

Alois W. Graf, chairman of the Chicago Section of The Institute of Radio Engineers, has announced the appointment of committee chairmen and vice-chairmen for the various committees of the Chicago section. These men, who are appointed for a period of one year, are as follows: *Meetings and Papers:* chairman, R. E. Samuelson, the Hallicrafters Company, vice-chairman, C. A. Petry, United Air Lines. *Headquarters Relations:* chairman, W. O. Swinyard, Hazeltine Research, Inc., vice-chairman, V. J. Andred, Andrew Company. *Membership:* chairman, R. M. Krueger, American Phenolic Corporation, vice-chairman, Karl Kramer, Jensen Radio Manufacturing Co. *Publicity:* chairman, H. S. Renne, Radio-Electronic Engineering, vice-chairman, E. O. Ross, A. C. Nielsen Company. *Arrangements:* chairman, R. P. Dimmer, Automatic Electric Company, vice-chairman, H. E. Armstrong, Doolittle Radio. *Banquet:* chairman, Cullen Moore, Galvin Manufacturing Corp., vice-chairman, R. T. Van Niman, Motrograph. *Engineers Status:* chairman, Chester Lytle, Consulting Engineer, vice-chairman, Mahlon Kenny, J. P. Seeburg Corporation. *Special Events:* chairman, Kenneth Jarvis, Consulting Engineer, vice-chairman, Karl E. Rollefson, Muter Company. *Procedure:* chairman, LeRoy Clardy, Swift and Company, vice-chairman, Paul Smith, Galvin Manufacturing Corporation. *Constitution & By Laws:* chairman, Walter Schwalm, Zenith Radio Corporation, vice-chairman L. G. Nierman, University of Chicago. *Education:* chairman, C. S. Roys, Illinois Institute of Technology, vice-chairman, G. H. Fett, University of Illinois. *Ways & Means:* chairman, Alfred Crossley, Consulting Engineer, vice-chairman, Wm. Schlessinger, Electronic Development Laboratories. *Historical Data:* chairman, Elizabeth Kelsey, Zenith Radio Corporation, vice-chairman, Nathan W. Aram, Zenith Radio Corporation. *Recording Secretary:* Leo Killian, Raytheon Manufacturing Company.

Mr. Graf has inaugurated a new policy in the Chicago Section with respect to committee appointees. At the request of the appointee, a copy of the letter of appointment is sent to his superior or to anyone else he may designate. This serves to call attention to the appointment and to emphasize its importance. A greater understanding on the part of executives and "higher-ups" of the importance of committee work and the time required for such work is expected to result.

The officers for the Chicago Section for the coming year are: Alois W. Graf, Chairman; Karl Kramer, Vice-chairman; Don Haines, Secretary.

I.R.E. People

John G. Leitch

John G. Leitch

Since his return in December, 1945, from a four-year tour of active duty with the Navy, Commander John G. Leitch (A'32–M'36–SM'43), United States Naval Reserve, has been serving as director of construction for WCAU, Philadelphia, Pennsylvania. He has been supervising the planning of that station's new radio and television center.

Educated at the University of Pennsylvania, Commander Leitch's career in the commercial communications field began in 1918 with the Signal Corps in World War I. After the Armistice, he shipped with the Merchant Marine as a radio operator until 1922, when he became a radio inspector for the Marconi Company. From 1924 to 1928, he worked for the Government as a United States Radio Inspector, and in 1929, he joined the staff of WCAU. Commander Leitch served as chief engineer of WCAU and its short-wave station W3XAU until 1932, when he was appointed technical director of the station, a post which he still retains.

An officer in the Naval Reserve since 1927, Commander Leitch was called to duty in 1941 and successively served as communications officer, in-shore patrol and Naval Air Station, at Cape May, New Jersey; assistant district communications officer, fourth Naval district; officer in charge, United States Naval Station in Greenland; officer in charge, communications team, attack force for the Marshall, Mariana, and Gilbert Islands; staff communications officer on the U.S.S. *Pennsylvania;* staff officer C-in-C, in the Pacific; and on the staff of the Director of Naval Communications in Washington, D. C. Commander Leitch's service awards include the Victory Ribbon for World Wars I and II, the American Defense, Atlantic Theater, European Theater, Pacific Theater (3 stars), Navy Unit Commendation (1 star), Presidential Unit Citation (1 star), and the Commendation Ribbons.

A member of the Veteran Wireless Operators Association, Commander Leitch held a commercial first-class operator's license from 1918 to 1925, an extra-first-class license from 1925 to 1932, and a first-class radiotelegraph and radiotelephone license from 1932 to the present date.

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Theodore A. Cohen

Theodore A. Cohen (J'27–A'30–SM'44) has announced the formation of the Taco Engineering Company, located in Chicago, Illinois. The firm will specialize in electronic and electromechanical automatic-control equipment and processes. Founder and former vice-president and chief engineer of the Wheelco Instruments Company, Mr. Cohen was responsible for the development of Capacitrol and Flame-otrol products.

Holder of numerous patents and an author of technical articles, Mr. Cohen is a lecturer on electronic applications and design, electrical measurement, heat flow, and other allied subjects. He is a member of the application committee on automatic control of the American Society of Mechanical Engineers, the committee on research and recommended standards of the Instrument Society of America, and a senior member of the Western Society of Engineers, the Electro-Chemical Society, and the American Society for Metals.

Theodore A. Cohen

❖

Victor H. Fraenckel

Victor H. Fraenckel (A'36), of the General Electric Company's research laboratory, has been awarded the Medal of Freedom by the War Department for his wartime services. In 1943 Mr. Fraenckel went to England as acting director of the American-British Laboratory to work on radio and radar. In 1944 he was made consultant to the staff of General Spaatz of the United States Strategic Air Force in Europe. Later he was scientific adviser to G-2 (Intelligence) on General Eisenhower's staff at Supreme Headquarters.

George Mucher

George Mucher (A'36) has been named executive vice-president of the Kurman Electronics Corporation, which recently was acquired by the Clarostat Manufacturing Company.

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Arthur E. Harrison

Arthur E. Harrison (A'41–SM'45) has joined the faculty of Princeton University as assistant professor of electrical engineering. His work will include graduate courses and research on microwave vacuum tubes and ultra-high-frequency measurements.

Dr. Harrison received the B.S. degree in electrical engineering from the University of California in 1936. From 1936 to 1939 he was a teaching Fellow at the California Institute of Technology, and received the M.S. degree in 1937 and the Ph.D. degree in 1940. He was engaged in research work for the department of mechanical engineering at the University of California during 1940. In May, 1940, Dr. Harrison joined the klystron laboratory staff of the Sperry Gyroscope Company at San Carlos, California, and has been engaged in klystron research and applications work at that company's engineering laboratories at Garden City, New York, since their organization in November, 1940.

Numerous articles on klystrons by Dr. Harrison have appeared in the Proceedings of the I.R.E. and Waves and Electrons and other publications, and he is the author of a book, "Klystron Tubes," which will be published early in 1947. His activities have also included talks before several I.R.E. sections and the National Electronics Conference, and participation in the first amateur communication by microwaves when the amateur bands were reopened following the end of the war. Dr. Harrison was chairman of the Papers Committee for the 1946 I.R.E. Winter Technical Meeting and has served on several other I.R.E. committees. He is a member of Sigma Xi, Tau Beta Pi, and Eta Kappa Nu.

Arthur E. Harrison

Waves and Electrons Section

Dale Pollack

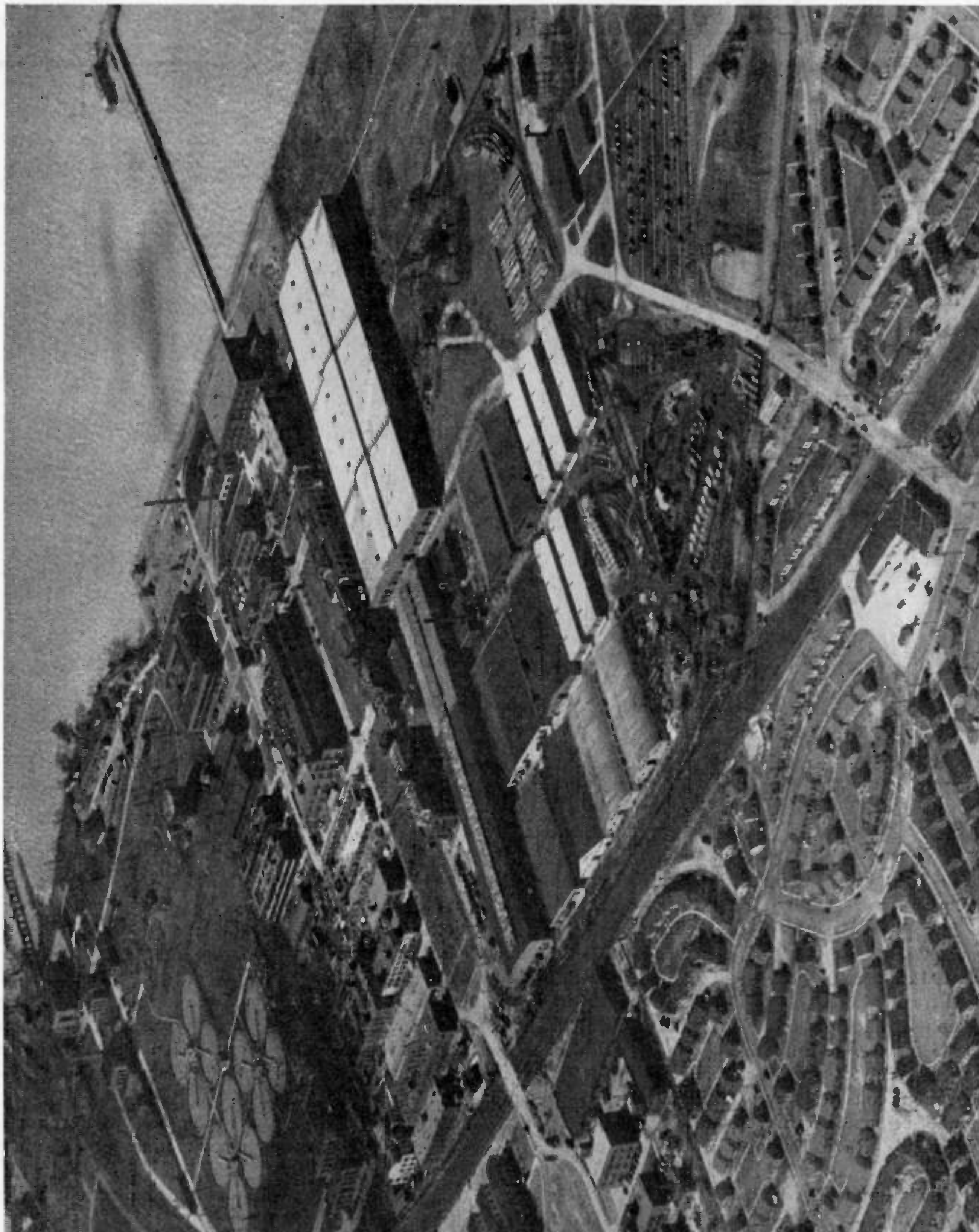
Chairman, Connecticut Valley Section, I.R.E.

Dale Pollack (J'30–S'35–A'38–SM'43), the new chairman of the Connecticut Valley Section of The Institute of Radio Engineers, was born July 26, 1912, in St. Louis, Missouri. He attended Columbia University school of engineering and, later, the Massachusetts Institute of Technology under Tau Beta Pi and Charles A. Coffin fellowships, receiving the D.Sc. degree in electrical engineering there in 1940.

From 1936 to 1939 Dr. Pollack was with the RCA Manufacturing Company in Camden, New Jersey, in the advanced transmitter development section, working on modulation problems. He joined the technical staff of the Bell Telephone Laboratories in Whippany, New Jersey, in 1940, where he engaged in radar systems development. From 1943 to 1946 he was associated with the Templetone Radio Manufacturing Corporation in New London, Connecticut, as chief engineer, and later as vice-president in charge of engineering. Dr. Pollack is presently engaged in independent consulting and development in frequency modulation, his special field.

A number of papers by Dr. Pollack have appeared in the technical periodicals. He is the author of a section in Keith Henney's "Radio Engineering Handbook," and co-author of a textbook on frequency modulation to be published.

Dr. Pollack, having served on various committees in his three years of membership in the Connecticut Valley Section, was vice-chairman last year. He is also a member of Sigma Xi and Tau Beta Pi.



Official U.S. Navy Photograph

THE UNITED STATES NAVAL RESEARCH LABORATORY AT BELLEVIEW, WASHINGTON, DISTRICT OF COLUMBIA.

The rapid development of the communications and electronics field, and its present and potential importance in times of peace and war, are clear to farseeing Governmental officers. The Institute of Radio Engineers has consistently endeavored to contribute to the advancement of this field. It is accordingly encouraging and stimulating to receive a message from Fleet Admiral Chester W. Nimitz, Chief of Naval Operations of the United States Navy. The readers of the PROCEEDINGS OF THE I.R.E. AND WAVES AND ELECTRONS will gain a clear picture of the importance of Naval contributions to this field and the desirability of further co-operation with the Armed Forces from the accompanying paper by Commander Delbert S. Wicks, United States Navy.—*The Editor.*

The United States Naval Reserve*

DELBERT S. WICKS†

ON August 31, 1945, scarcely two weeks after the surrender of the Japanese in Tokyo Bay, the United States Navy had reached a personnel strength of more than 3,400,000; of these, nearly 3,000,000 were Reservists on active duty.

As demobilization nears completion with Reservists returning to civilian status and more and more ships of the fleets being inactivated, the peacetime Naval Reserve organization is already activated and growing.

Pictured above is the new gold lapel pin authorized by the Navy Department to denote members of the Naval Reserve not on active duty.

The present Naval Reserve was established by Congress under the public law known as the "Naval Reserve Act of 1938." This act divides the Naval Reserve into four components: Organized, Volunteer, Merchant Marine, and Fleet Reserve.

The Organized Reserve is to be composed of trained Reservists in the numbers and skills that will be necessary immediately in the event of mobilization. These men and officers obligate themselves to attend weekly drills in Naval Reserve Armories and to perform an annual two-weeks' training period, usually at sea. They receive payment for these drills and the annual training duty.

The Volunteer Reserve is composed of the men and officers of the Naval Reserve, not members of other components, who are qualified or partially qualified for prescribed mobilization billets. While in the Volunteer Reserve they do not obligate themselves to attend drills or perform annual training duties.

The Merchant Marine Reserve is composed of those who follow the sea as a profession or are employed in connection with the seafaring profession.

The Fleet Reserve is composed of men and officers with prior service in the regular Navy who have enlisted in or been appointed to the Naval Reserve and been assigned to the Fleet Reserve. They are in a nondrilling status and receive retainer pay.

Under the Naval Reserve Act of 1938, the Naval Reserve is administered by the Secretary of the Navy as a component part of the United States Navy. In the Navy Department there is a flag officer with the title of Assistant Chief of Naval Operations (Reserve) and Director of Naval Reserves. The present and first officer holding this title is Rear Admiral John Gingrich, U. S. N. The Chief of Naval Personnel has been charged by the Secretary of the Navy with the direct administration of the Naval Reserve program for all personnel and training matters, and an Assistant Chief of Naval Personnel (Naval Reserve) has been appointed, with a staff for direct planning in connection with Naval Reserve matters. The Naval Reserve program in the field is conducted by the Commandants of the

The rapid advancement of science in the electronics and communications fields during the war, which produced such devices as radar, loran, and sonar, continues in this postwar period. It is imperative that the United States Navy and the Naval Reserve keep abreast of this advancement and utilize it in maintaining a modern Navy and a properly trained Naval Reserve as part of our national defense.

Active participation of leading communications and electronics engineers in the Naval Reserve program will greatly benefit the Navy and this country, and The Institute of Radio Engineers is regarded as an agency likely to be of major assistance in this regard, as indeed it was to all branches of the Armed Forces during the war.

C. W. Nimitz

Fleet Admiral, United States Navy
Chief of Naval Operations

* Decimal classification: R565×R070. Original manuscript received by the Institute, August 9, 1946.

† Commander, United States Navy, Bureau of Naval Personnel, Navy Department, Washington, D. C.

Naval Districts, who are assisted in each district by an officer with the title of District Director of Naval Reserve. The Chief of Naval Air Reserve Training conducts the Naval Air Reserve program.

The Organized Reserve within the Naval Districts is composed of brigades, battalions, divisions, and squadrons. The division is the basic unit of the Organized Reserve and normally comprises 200 enlisted personnel and thirteen officers. In a locality where there are two or more divisions to be formed, a battalion staff will be organized in command of these divisions, and in certain cities where more than one battalion will be formed, a Brigade Commander will be named to head the program. Squadrons are units of the Naval Air Reserve program.

The Organized Reserve ultimately may have armories in 250 cities, many of these armories being city- or state-owned buildings. In some 89 cities, Quonset-hut-type armories will be erected. This type of armory uses three of the largest Quonsets, with a framed building across the end of the huts to join them and furnish additional training space.

A total of 168 ships has been assigned to the Naval Reserve thus far, including destroyers, destroyer escorts, submarines, and numerous smaller craft. These ships are spotted along both the East and West Coasts, on the Mississippi River, and on the Great Lakes, to augment training facilities for the Reserve program.

A number of the divisions in the Organized Reserve will be formed for training of submarine personnel. Other divisions will be known as officer divisions and will train officer personnel only in connection with various specialities such as intelligence, electronics, supply, and similar subjects.

The Naval Air Reserve program, administered directly by the Chief of Naval Air Reserve Training and designed to keep the Reserve complement of the naval air arm prepared for mobilization, trains both air and ground aviation personnel. Training subjects include gunnery, bombing, combat and formation tactics, instrument flying, and air navigation. Modern navy planes of most types are being used.

Electronics has a big share in Naval Reserve plans. Officers and enlisted men associated with the various phases of naval electronics are known as Electronic Warfare personnel. The term Electronic Warfare includes not only technical electronics but communications, antisubmarine warfare, combat-information-center organizations, and such related subjects as the guided-missile, infrared, and nuclear-physics programs. It is the policy of the Naval Reserve to promote the science of technical electronics as both the maintenance arm and as a research and development arm of naval electronic warfare.

Electronic Warfare personnel receive training in the Organized Reserve divisions along with the men and officers of other classifications and ratings. In the Volunteer Reserve, Electronic Warfare Companies and Platoons are formed for drilling on a volunteer basis. These volunteer units train Electronic Warfare personnel exclusively. Dependent upon appropriations, drill pay and annual training duty pay will be provided for members of these specialized volunteer units. Many of the Companies and Platoons will use the Armory facilities of the Organized Reserve. Wherever this is not convenient, they will have their own meeting places and necessary equipment. Electronic Warfare Companies may also be formed at various colleges and universities, but such units will not be a part of Naval Reserve Officers' Training Corps program.

The Electronic Warfare Company is normally composed of five officers and forty enlisted men, while the Platoon has one officer and up to nine enlisted men. In addition to their own equipment, which includes radio, radar, sonar, loran, test equipment, training devices, publications, and electronic laboratory equipment, Electronic Warfare personnel in both the Organized and the Volunteer Reserve will make as much use as possible of regular Navy facilities in furthering their training. Methods of training include classroom lectures by regular instructors and visiting lecturers, maintenance and operation of equipment in Naval Reserve shore facilities and on ships assigned to the Naval Reserve, assignment of laboratory problems and homework, extensive use of training films, synthetic training devices, recordings and correspondence courses, visits to laboratories (civilian and naval) and to certain manufacturing plants, and widest possible use of regular Navy activities. Competent men and officers of the Naval Reserve are required as instructors and consultants in the Naval Reserve training program. It is expected that many Naval Reserve officers who are electronic engineers will offer their services one or two evenings per week as Reserve instructors in their localities.

Through the office of the Assistant Chief of Naval Personnel (Naval Reserve) in the Navy Department, liaison will be maintained with such organizations as The Institute of Radio Engineers, the American Radio Relay League, electrical and electronic engineering departments of various universities and colleges, and manufacturers of electronic equipment. The advice and aid of these groups will be sought in formulating Naval Reserve policy regarding electronics and in providing visiting lectures.

The plans for the Electronic Warfare component of the Naval Reserve entail a large number of men and officers in training, in addition to Naval Reserve instructors and regular Navy personnel required for administration. With the highly technical training involved and the increasing complexity of naval applications, suitable training for sufficient numbers of Naval Reserve Electronic Warfare personnel becomes an ever more important and more difficult task. By providing armories and modern equipments in many communities throughout the United States of America, the Navy via the Naval Reserve expects to accomplish this important task satisfactorily.

Should I Become a Radio Engineer?*

ROBERT B. JACQUES†, MEMBER, I.R.E.

Summary—A discussion of the problems facing the ex-servicemen and high school graduates who wish to enter the field of radio engineering, and some suggestions as to the procedure that might be followed.

"SHOULD I become a radio engineer?" This question is being asked by thousands of young men of college age, both those who have seen service in the armed forces and those who are just being graduated from high school. The answer, for those of you who are willing and able to spend the amount of time and perseverance required in obtaining the proper education, is "emphatically yes."

In the First World War the automobile and other mechanical devices became of paramount importance to the armed services. The demand for mechanical engineers was incredible. World War II has been rightly referred to as "electronic warfare." The advent of radar, with all its branches, the innumerable types of communications systems and radio-controlled projectiles created a demand for radio engineers and technicians that was astronomical in numbers compared to the need for mechanical engineers in the First World War. A further complication was added in that not only was there a great need for engineers and technicians to design and build electronic equipment but there were also needed tens of thousands of skilled technicians to operate the equipment in the field. Nearly anyone could learn in a few weeks to drive and service a piece of mechanized equipment, such as existed in World War I, but it took months and years of training to prepare a man for operating and servicing complicated radar and communications gear.

To provide for this situation, the armed forces established schools of nearly every level at various colleges and also at a great number of service posts. They then began to grind out the large numbers of engineers, technicians, and operators needed to keep the electronics equipment operating in the field. A continual battle developed between the military and industry for the services of personnel trained in any branch of the radio field. The armed services needed a great many men with college degrees to supervise and maintain the complicated pieces of electronic equipment then in use. On the other hand, industry could not produce the equipment without the help of men with college degrees in electrical engineering. As a result of this situation, many men were able to finish their schooling and obtain a degree only by signing up with the armed forces beforehand. In addition, a great many men who had previously never intended to enter the field of radio engineering were suddenly drafted and sent to various radio schools for training as technicians.

A great many problems arose out of all this. If the man who managed to finish school and obtain his degree in electrical engineering was then able to get employment in a draft-free engineering occupation, he was fortunate. He is now firmly entrenched in the radio industry and is in an excellent bargaining position as his services are in great demand, primarily because of his three to five years of experience. On the other hand, the man who obtained his college degree and entered the armed forces, usually as an officer, is not in such a fortunate position. Although he may have had a year's additional training in an armed forces' radio or radar school, and several years' experience installing, supervising, and maintaining complicated electronic equipment in the service, he has not had the exact type of experience that the radio industry wants. By some companies he is considered as a newly graduated college man and may be started at the same level as college graduates who were not in the service. There should be no misunderstanding about the availability of jobs in the radio industry for these men. There are many jobs available that will use their skills to the utmost. However, they will not always start in at a level equal to their classmates who did not enter the services. The problem of either one of the above groups is not serious, since they are both accepted as radio engineers.

The man who was not able to finish college is in a less favorable position. True, he has had from one to three years of college training and perhaps another year of training under army or navy supervision, but he does not have a college degree in electrical engineering. In a great many instances he is fitted as a technician, immediately upon discharge from the services, and usually he can do a good job in that capacity. The openings for such men of technician level, however, are fewer as a general rule, as men of that level who worked for industry during the war have almost saturated the reconverting industry. One sure plan is open to men in this situation. If they are really interested in becoming radio engineers, they must take advantage of the GI bill and go back to school to finish their work toward a degree. Actually, the best opportunity for contact with industry occurs at the time of graduation from college, because industry has personnel men who make the rounds of the colleges at graduation time, looking for men to do specific jobs.

Another class of men is those who obtained degrees in branches of study other than electrical engineering and then entered the armed services in the radio field. These men had some extra training provided by the army and navy in the field of radar and communications and several years of experience in service in this field. Many of them like the field of radio so much that they wish to remain in it, but they may have difficulty obtaining a job at a level much higher than technician because of their lack of a degree in electrical engineering. These men should find a way to go back to college long enough to obtain the extra courses necessary for their degree. Usually it will not take more than a year and the benefits of a degree are certainly worth the effort.

For the man just graduating from high school the horizons are unlimited. It appears that the radio and electronics industry has only started to grow. The various new branches, such as television, frequency modulation, pulse modulation, radar and other forms of radiolocation, and industrial electronics, will continue to spread the radio industry into larger and larger fields. If the high-school graduate will enroll as soon as possible in the electrical-engineering school of a college or university, by the time he obtains his degree he will be in an excellent position to enter the radio industry. Reconversion will be over by then and the industry will be rolling in high gear. Job opportunities should be very numerous and it will be possible to choose a specific field of interest.

A great many men who were not able to finish college, whether they were in the armed services or not, have married or taken on other responsibilities. They feel that they cannot afford to go back to school because of lack of income. This is sheer nonsense. At some of our larger universities, as high as ten per cent of the students are married or have grave responsibilities and they manage to live very well. There is always part-time work to be had around a large university, either in the university departments or in business establishments near the campus. A resourceful individual can always find a solution to the problem.

Other men feel that they are too old to go back to school. Again, these men are wrong. A college degree is worth just as much at 35 years of age as at 22. Actually, it is worth more. Industry looks on an older man who obtains his degree as a valuable asset to their company; the very fact that he did obtain it shows diligence and perseverance in his chosen field.

We have talked about two classes of men, radio engineers, and technicians. It is difficult to draw a sharp line between the two. In general, a radio engineer is a man who can take responsible direction of design, development, and supervision of construction of radio or electronic equipment. The technician, on the other hand, usually does the construction and spade work for the engineer. It is possible to start as a technician and, by hard work and outside study, break over into the radio-engineering field, but it takes a very long time and the road is fraught with disappointment. In a great many cases technicians receive higher pay than beginning engineers, but the disparity does not last long, as the engineer usually rises rapidly to the higher income brackets. One point must be made very clear; without a college degree, a man must invariably start in industry as a technician, and he will find it very difficult to change his status to that of a radio engineer.

In conclusion, remember that the radio industry will not be saturated with *good* engineers for many years to come. If you really like radio and electronics, and are willing to work hard to obtain a place of engineering prominence in this field, the door is wide open. That door is the entrance to an accredited college or university which offers courses leading to a degree in electrical engineering and/or communications engineering.

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Radio Proximity-Fuze Development*

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Summary—**The general principles governing the design of radio proximity fuzes are presented. The paper deals primarily with fuzes for smooth-bore projectiles,[1] such as bombs, rockets, and mortars. Illustrations and descriptions of the various fuzes in this category which were developed during World War II are given. Within security regulations, there is a reasonably detailed discussion of the performance and construction of fuze components, such as the oscillator, the amplifier, the antennas, the power supply, and the safety and arming mechanisms. There is also a brief description of production practices and problems and methods of inspection and quality control.**

Introduction

Electronic arts are generally linked to intelligence, and the radio proximity fuze follows the pattern. Intelligence might be described as the ability to adopt or change a course of action according to the circumstances of the moment to give the most effective result without external influence. This sense, which is the prime feature of the radio proximity fuze, fulfills one of the dreams of the ordnance man and provides a fuze which increases weapon effectiveness manyfold. If a projectile can be made to explode at its closest approach to an airplane target, the effective size of the target is increased greatly; if a projectile can be made to explode above the ground, fragments are sprayed out over a wide area instead of either being buried in the ground at the point of contact or directed harmlessly upward.

The radio proximity fuze was developed to meet these requirements. It is an extremely small transmitting station with a receiver which detects any reflections of the transmitted wave. It works on the Doppler principle and operates whenever the amplitude of the reflected signals exceeds a predetermined value. There is the additional restriction that the velocity of approach must be such that the resulting Doppler frequency lies in the relatively narrow frequency band for which the fuze was designed.

As certain specific details of fuze construction still fall under the heading of classified information, it is necessary to introduce some generalities in this paper in order to meet security regulations.

The impact of this new application of electronics on military science and tactics is enormous. It is the counter-weapon to airplanes and robots raiding ships or cities. It is a new offensive weapon for airplanes. When used against entrenched troops or troops on the march, it provides a new order of importance for the shell, bomb, or rocket with which it is used. Some of the foremost military leaders have said that it precluded troop movements in the open. Remembering that most military tactics depend upon the movement of troops and supplies for sudden attacks and quick support of defenses, one can begin to see the importance of the application.

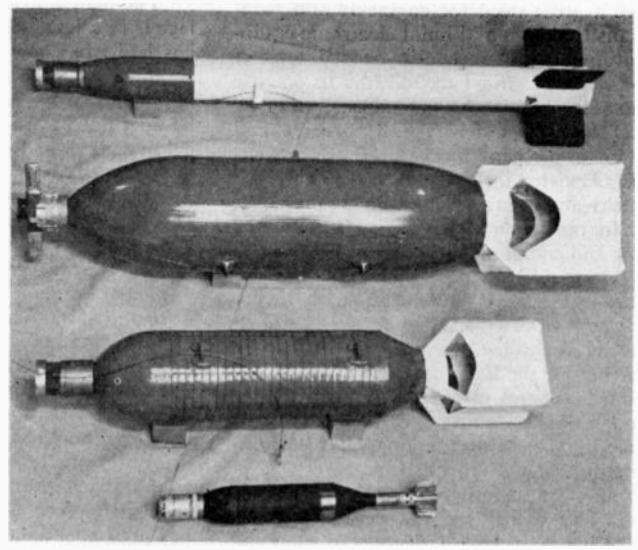

Fig. 1—Radio proximity fuzes mounted on projectiles. Top: 5-inch high-velocity aircraft-fired rocket with ring-type rocket fuze. Second from top: 500-pound general-purpose bomb with bar-type bomb fuze. Third from top: 260-pound fragmentation bomb with ring-type bomb fuze. Bottom: 81-millimeter mortar shell with streamlined ring-type fuze.

The work on proximity fuzes started in this country in August, 1940, under Office of Scientific Research and Development auspices. In the spring of 1941, in order to press the development with maximum efficiency, the Navy assumed responsibility for the development and procurement of proximity fuzes for rotating projectiles, such as antiaircraft and artillery shells, while the Army directed the development of fuzes for nonrotating projectiles, such as bombs, rockets, and mortars. This paper deals with the Army phase of proximity-fuze development. Some of these fuzes mounted on projectiles are shown in Fig. 1.

* Decimal classification: R560.2. Original manuscript received by the Institute, February 25, 1946. This paper is based upon the work of the Fuze Development Staff, Ordnance Development Division, National Bureau of Standards, under the direction of Harry Diamond. The program was conducted under the sponsorship of the Army Ordnance Department and Division 4, NDRC, and with the assistance of the Signal Corps. The radio fuze development and production programs were successful because of the high order of cooperation between military and civilian government agencies and the American manufacturers. The free exchange of information, even between normally competing manufacturers, contributed immeasurably to good fuze design and production. Principal manufacturers of bomb, rocket, and mortar fuzes were Emerson Radio & Phonograph Corporation, Friez Division of Bendix Corporation, General Electric Company, Globe-Union, Inc., Philco Corporation, Western Electric Company, Westinghouse Electric and Manufacturing Company, The Rudolph Wurlitzer Company, and Zenith Radio Corporation. Principal tube manufacturers were General Electric Company, Raytheon Manufacturing Company, and Sylvania Electric Products, Inc.

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[1] Distinction is made between the application to rotating and nonrotating projectiles. The difference lies principally in factors such as power supply, arming mechanisms, and physical structure. The first two are dependent primarily on the conditions of acceleration and motion. The physical structure is governed by the size and contour of the projectile.

The existence of an effective radio fuze was one of the best-kept secrets of the war. Scientists of all countries had the basic concept, but only the United States and her Allies were able to work from the concept to practical and effective operation and production, for the radio proximity fuze is a paradox. Simple in general theory, it is extraordinarily complex in the variety of applied arts which are combined in its practical aspects.

Much of the necessary engineering and development work was devoted to meeting exacting military requirements, such as: (1) the fuze must fit existing projectiles using the same fuze well as the mechanical fuzes, and it must not project more than approximately five inches beyond the well; (2) it must be capable of withstanding long storage conditions at high and low temperatures and of operating under these conditions; (3) it must not alter the ballistic characteristics of the projectile; and (4) it must meet other strict requirements relating to time of activation, safety, and performance.

The size limitations for radio proximity fuzes were fixed by military necessity. One might think that in the case of a five-hundred- or one-thousand-pound bomb a few extra cubic inches or an extra pound or two would not be important, but bombs and bomb bays were already designed and in use. A fuze projecting so far as to prohibit loading a fuzed bomb into the bomb bay would be useless. Ballistic tables for all bombs were available, and if the radio fuze affected the trajectory and changed the bombing tables appreciably, use of the fuze would be prejudiced. In the case of the smaller projectiles, such as the trench mortar, size and weight limitations were even more severe. One of the 81-millimeter mortar shells weighs approximately eight pounds, and unless the radio fuze is light and fairly well streamlined, the range of the mortar is reduced—a severe handicap to its military effectiveness.

Other basic difficulties are readily apparent. Mortar fuzes must withstand acceleration of 10,000 *g*. In the fuzes for bombs and rockets, the projectile vibrations caused by flight velocities approaching or exceeding the speed of sound required great rigidity in the design of the fuzes and their components. Some idea of the energy producing these vibrations may be had by considering conditions at terminal velocity. Air friction and turbulence prevent further acceleration and do work on the bomb, which work appears as vibration and heat. For a one-thousand-pound bomb at a terminal velocity of 1000 feet per second, the rate of energy dissipation is 1,000,000 foot-pounds per second, or 1356 kilowatts. Taking into account the desirable requirements of low cost and small size, and with the further realization that an extraordinary degree of electronic stability is needed for satisfactory operation, it is evident that the performance requirements for these electronic devices are very strict.

These restrictions required the development of new, very small and strong components. It is fortunate that "small" and "strong" go together. Weight is proportional to the cube of the linear dimension, while the supporting area is proportional to the square of the linear dimension. Thus, reduction in size by a factor of 10 results in an object whose strength under acceleration is increased by 10. Resistance against centrifugal forces and bending moments is also greatly increased by a reduction in size. This is the reason that electronic components, generally considered delicate, can be constructed so as to withstand the high vibratory and accelerating forces which are developed in the various projectiles.

General Description

The radio fuze is essentially an oscillating detector. The operating signal is furnished by the combination of the wave reflected from the target with the voltage of the local oscillator. The time of travel of the radiated wave from the oscillator to the reflecting surface, or target, and back results in a phase difference between the transmitted and reflected wave. If the distance to and from the reflecting surface changes, the relative phase changes. When the oscillating detector is approaching the reflecting surface, the phase change appears as an increase in the frequency of the reflected wave, each returning wave front reaching the detector *sooner* than it would if the oscillating detector were stationary. Thus, the apparent distance between wave fronts is shorter and the frequency is higher.

The actual frequency of the returning wave (since it must go to, and return from, the target) is

$$f_1 \text{ (the outgoing frequency)} + 2\,\frac{\text{relative velocity}}{\text{wavelength}}$$

and the "difference" beat frequency is

$$2\,\frac{\text{relative velocity}}{\text{wavelength}}.$$

The latter is the signal used to detonate the fuze when it approaches the reflecting target at a preselected velocity (hence beat frequency) and when it is close enough for the reflected wave to have sufficient amplitude.

At useful operating ranges of from 20 to 70 feet, the amplitude of the reflected wave seen by the detector is of the order of a small fraction of a volt. Amplification is necessary to make this voltage large enough to operate the detonator control circuit, usually a thyratron. A single-tube amplifier, whose pass band is designed to favor the reflected signal over spurious noise or other signals, is used to increase the amplitude of the detected beat frequency to several volts, enough to cause the standard control circuits to function.

A power supply and a mechanical safety arrangement to prevent premature operation of the detonator completes the primary components of the fuze.

VT fuzes are designed to certain over-all sensitivities which, obviously, involve both oscillator and amplifier design. Greater amplifier gain may completely compensate for a weak or inefficient oscillator detector, but if a weak oscillator is used without a commensurate reduction in the noise voltage (the peak rectified noise voltage at the detector output), the signal-to-noise ratio is reduced.

Throughout the development and production of VT fuzes, electrical stability in the presence of severe vibration was a prime problem. Although generally called an electronic fuze, the structural and mechanical design required a great deal of attention. Improper design might cause the fuze to operate spontaneously prior to reaching the target. A large part of the engineering and development work was directed toward obtaining the best performance possible, for the same bomb cannot be dropped twice. The work was directed along three general lines: (1) improvement of circuit stability; (2) reduction of tube microphonics; and (3) reduction of vibration introduced by unbalance in the high-speed generator.

Certain cardinal precepts were established early in the program. Shock mounting was not used because shock mounts have a low natural period with a multitude of harmonics. It was found preferable to make the parts "so rigid that there could be no relative motion." Of course, this really means that the natural resonances of all parts were placed out of the range of the signal frequencies at which the amplifier was responsive. It was accomplished by extremely solid and rugged mounting of all parts and by careful design of all components. Ideally, all parts should be made as a block so that the completed fuze would be literally as solid as a brick. This ideal condition was approached by cementing the oscillator components into cavities in a solid insulator in the form of a disk one-half inch thick, the assembly being tightly fastened to a suitable heavy metal casting. The amplifier was built on a light bakelite or fiber chassis and set into a cavity in the heavy casting. The cavity was then filled with a potting material so that all parts were held rigidly in place.

The mounting of the fuze to the projectile was particularly important. For a given vibratory force, acceleration is inversely proportional to mass, and the effective mass is greatly increased if the fuze is made a rigid part of the projectile. Considering the vibration of the rotating system, a firm mounting between the fuze and the projectile did much to reduce its amplitude.

Fig. 2 shows a cutaway view of one of the bomb fuzes and general circuit diagrams of the primary fuze subassemblies. A more detailed discussion of each of these subassemblies follows.

The Oscillator

The primary problems of oscillator design are radio-frequency sensitivity, stability, and size. Sensitivity is defined as the absolute change in detected output voltage per unit change in antenna radiation resistance. It may be represented by the following equation:

$$\Delta E = \frac{S \Delta R_A}{R_A}$$

where ΔE is the change in detected output voltage, S is the sensitivity, ΔR_A is the effective change in radiation resistance, and R_A is the radiation resistance, the antenna circuit being tuned to resonance. In the limit, the equation for sensitivity becomes

$$S = \frac{dE}{\dfrac{dR_A}{R_A}} = \frac{dE}{d(\log R_A)}.$$

The latter form of equation suggests a simple method of measuring the radio-frequency sensitivity. Measurements are made of detector voltage E for various values of radiation resistance R_A. The range of radiation resistance is selected to cover the values of all projectiles on which the fuze is to be used.

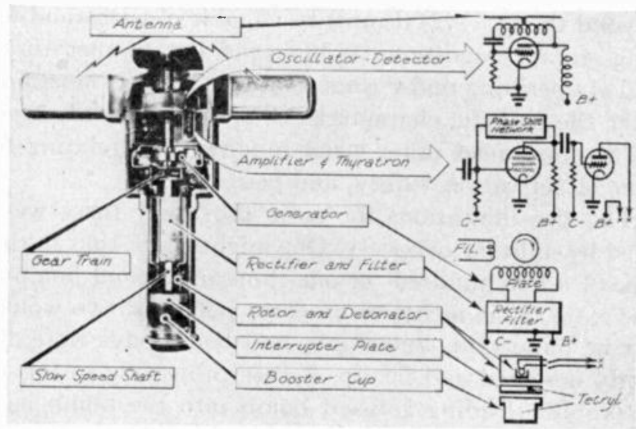

Fig. 2—Cutaway view of bar-type bomb fuze and circuit diagrams of primary fuze assemblies.

The next step is to plot the detector voltage against the log of the radiation resistance. The slope of this curve is $dE/d(\log R_A)$ and, therefore, is the radio-frequency sensitivity. Note that the unit of radio-frequency sensitivity is the volt, and, again, is interpreted as the number of volts change in detector voltage per unit of change of radiation resistance.

Any oscillating detector will have appreciable radio-frequency sensitivity for a reasonable range of radiation resistances. In a well-designed system, the oscillator is stable, and the sensitivity is high for radiation resistance values varying over a large range. This is an important factor in fuze design, since it allows use of the same fuze with a variety of projectiles, small and large. Class-C oscillators are generally used because this type gives high sensitivity with good stability and is largely independent of tube characteristics and radiation resistance.

In addition to considering the change in voltage in the presence of a change in radiation resistance, one must consider the absolute value of detector voltage E. For a given sensitivity, the lower we make the value of E, the lower will be the noise voltage. Any circuit which increases the sensitivity-to-noise ratio is to be preferred, even though the absolute signal voltage is low, for low signals are easily amplified.

Note, then, that the radio fuze does not require a detector which is sensitive in the usual sense; i.e., responsive to extremely weak signals. Efficiency is a better word; that is, we are interested in the *percentage* of the voltage developed by the oscillator that appears at the detector output when the oscillator approaches to a fixed distance from a given type of reflector. The higher the percentage, the more stable is the fuze.

The Amplifier

Fuzes have been designed to operate at distances up to 70 feet against aircraft and up to several hundred feet over ground. At these distances, the reflected signal is a small fraction of a volt. This low voltage does not provide a safe margin for controlling the gas relay (thyratron) used to detonate the fuze, and so it must be amplified to a reasonable working voltage. While this is the primary amplifier function, other considerations apply, without which satisfactory operation could not be attained.

The first of these is discrimination against microphonics and other stray noise. The Doppler frequency F lies in a rather narrow band for any individual fuze and projectile; that is,

$$F = \frac{2V}{\lambda},$$

where V is the relative velocity of the projectile and target and λ the wavelength, both in the same units. Bomb velocities, for instance, vary from about 400 to 1000 feet per second, depending on the altitude from which the bomb is dropped, while rocket velocities of projectiles used in World War II varied from 1000 to 1800 feet per second. Frequencies other than the corresponding Doppler frequencies play no useful role in the radio fuze, and every effort is made to reject them through the use of band-pass amplifier circuits.

The use of wind-driven alternators (described later) gives an additional reason for restricting the bandwidth of the amplifier. Many fuzes are required to be operative in less than a second, so that directly heated filaments must be used. By keeping the alternator frequency outside of the Doppler range, the frequency cutoff of the amplifier discriminates against the hum in the alternating-current filament supply to such an extent that filament center tapping is not needed.

Another consideration is the class of target. There are two general types—the ground, and the aerial target. The ground is considered to be a level plane, and the Doppler frequency is proportional to the vertical component of velocity. The aerial target as represented by the airplane has a complicated reflection characteristic whose reflecting power can be roughly compared with that of a tuned half-wave dipole, in so far as general characteristics are concerned. The actual reflecting power is determined by a series of field measurements.

To understand the factors affecting the optimum gain frequency characteristics of amplifiers, it is necessary to consider the directivity, or radiation characteristic, of the antenna. Nearly all radio fuze antenna systems are rather highly directional. Since the same antenna is used for transmitting and receiving, the sensitivity characteristic is the square of the radiation characteristic. Projectiles approach the ground at a variety of angles and the fuze should not detonate the projectile at heights above ground which are sharply dependent on the angle of approach; a uniform burst height is desired.

Depending on the type of antenna, the gain versus frequency characteristic is adjusted to give a uniform height of function for the fuze for any angle velocity of approach to the target. The two most common antenna types are the *longitudinal*, employing the body of the projectile as the antenna,[2] and the *transverse*, employing a bar as a dipole disposed at right angles to the projectile axis (Fig. 1). Directivity envelopes for longitudinal and transverse excitation, i.e., for ring-type and bar-type fuzes, respectively, mounted on bombs, are shown in (a) and (b) of Fig. 3. Minimum radiation occurs, of course, on the axis of the antenna in each case, and maximum radiation is roughly at right angles to that axis.

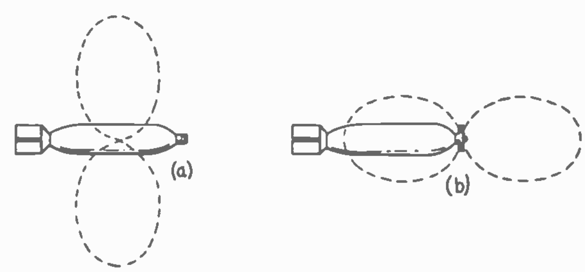

Fig. 3—Directivity envelopes for (a) longitudinal and (b) transverse excitation using, respectively, ring-type and bar-type antennas.

For the longitudinal type, it is obvious that the radiation is least for a vertical drop, and it reaches a maximum as the angle of approach with respect to the vertical is increased. Now since the vertical component of velocity is highest for high-altitude bomb releases, the angle with the vertical is small, the radiation is low, and the Doppler frequency is high. For this condition, high amplifier gain compensates for the low power radiated toward the target. Conversely, for low-altitude bomb releases, the vertical velocity is low, the angle with the vertical large, and the Doppler frequency low. Here, less amplifier gain compensates for the higher power radiated toward the target. By proper design of the amplification characteristic, the height at which the fuzed projectile functions may be held quite uniform, regardless of the altitude of release. This will be treated in more detail later.

The second type, the transverse antenna, has a substantially constant radiation toward the ground for all except extremely low-altitude releases, where the angle of fall with respect to the vertical is very large. The amplifier for this type fuze has essentially constant gain over the corresponding range of Doppler frequencies. Fig. 4 shows representative gain versus frequency characteristics for the two types of fuzes.

The radio fuze for aerial targets presents problems in amplifier design that differ from those of the application

[2] Radio-frequency energy is end-fed to the body through the antenna ring or cap of the fuze.

over ground. The requirement is that the fuze must function at the optimum point as it *passes* the target. The fragments of an exploding projectile have two velocities—one caused by the projectile motion, and the other by the explosion. The greatest concentration of fragments is at right angles to the path of travel of the projectile axis (statically). The projectile velocity combines with the velocity generated by the explosion to cause the equatorial spray of fragments to move forward of the normal to the projectile. Thus, the optimum point for detonation is that where the line from the projectile to the target makes an angle of from 15 to 30 degrees with the normal to the trajectory.

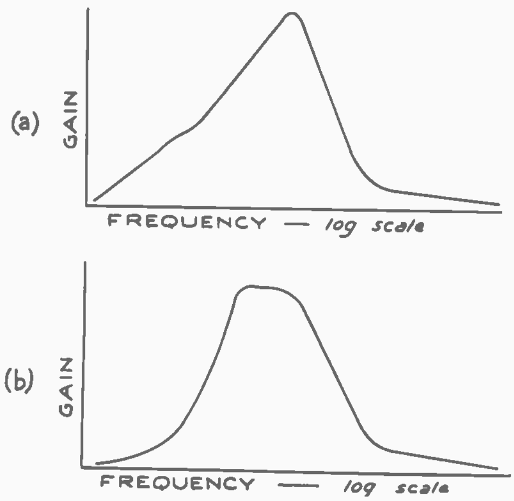

Fig. 4—Gain versus frequency characteristics for two types of fuzes. (a) Ring-type fuze. (b) Bar-type fuze.

The preferred type of antenna for aerial targets is that using longitudinal excitation, since radiation reaches the target only when the projectile approaches it. Consideration of the Doppler signal pattern, commonly called the *M* wave, as a fuze passes an aerial target will show the means of using the amplifier characteristic to control the burst point (Fig. 5(a)). Consider a projectile approaching an aerial target from a distance. The Doppler frequency depends on the *relative* velocity of the projectile and the reflecting target. For a target and a projectile traveling in the same direction,

$$F = 2\frac{(V_1 - V_2)}{\lambda}\cos\theta,$$

where V_1 is the projectile velocity, V_2 is the target velocity, and θ the angle between the projectile trajectory and the line connecting the projectile and the target. Thus, when the projectile is distant from the target, $\cos\theta \cong 1$, while at the instant of passing the target, $\cos\theta = 0$ (for an idealized point target).

As the projectile approaches the target, the Doppler frequency changes continuously from that corresponding to the difference of the projectile and target velocities to zero, being at all times proportional to $\cos\theta$. If the amplifier is peaked sharply at a frequency corresponding to some value of $\cos\theta$, the amplifier will be most sensitive at that frequency (or angle), and the fuze will be most likely to explode at the corresponding point on its trajectory, the exact point being influenced by the radiation pattern. A typical amplifier gain versus frequency characteristic is shown in Fig. 5(c).

The *M*-wave signal at the amplifier output is shown in Fig. 5(b). This is the *M* wave of Fig. 5(a) modified according to the amplifier gain for the varying frequency.

Most of the amplifiers use only one tube. The high degree of selectivity is shown in Fig. 4. It is obtained through the use of strongly regenerative-degenerative circuits. Noise or hum voltages large enough to overload the amplifier may appear at the input, but by feeding the corresponding out-of-phase voltage back from the output, the undesired voltages are bucked out and suppressed.

Conventional resonant inductance-capacitance circuits are used in combination with the feedback circuits to provide the flat-top band-pass characteristic needed for the transverse-excitation type of fuze. The practice of tuning the resonant circuit to the lower limit of the desired frequency band was widely used. Other types of circuits are, of course, possible, but space limitations and circuit complexity prejudiced their use.

Radiation, Reflection, and Operating Range

The distance at which a reflected signal is large enough to operate the radio fuze and explode the projectile is dependent on several factors, both internal and external to the fuze. The internal factors which control the height of function are radio-frequency sensitivity, over-all amplification, shaping of the amplifier, thyratron characteristics, and the time delays in all the electrical and explosive paths in the device. External to the fuze, controlling factors include the radiation pattern of the projectile acting as an antenna, external geometry of the fuze-projectile combination, radio frequency, reflection coefficient of the target, geometry of the target,

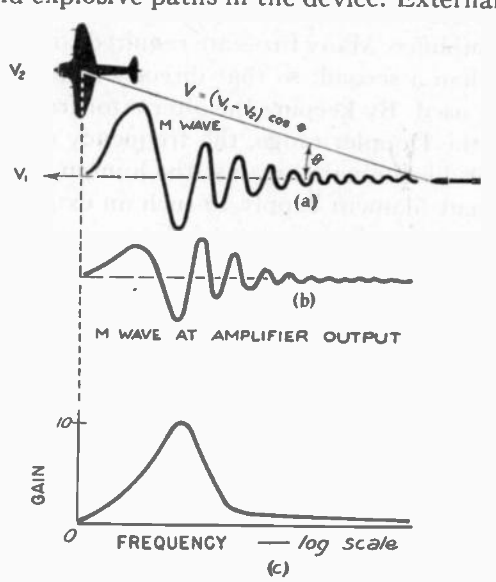

Fig. 5—(a) Doppler signal pattern, or *M* wave. (b) *M*-wave signal output from amplifier. (c) Gain versus frequency characteristic of the amplifier.

angle of approach, and the relative velocity of projectile and target.

Although the above factors present a most unwieldy number of variables, it has been possible by a combination of theory with laboratory and field experiments to arrive at formulas for computing burst distances with considerable accuracy. The general method of solution is the same for any type of target, provided some knowledge of the reflecting properties of the target is at hand. For an aerial target, the reflection coefficient, both in magnitude and phase, as a function of aspect angle, may be determined experimentally. Actually, however, the reflection coefficient of such targets varies so much with angle of approach and type of construction (i.e., metal, plastic, etc.) that average figures are assumed for various targets and used for all computations regarding this target. Thus, for example, a certain type of airplane might be equivalent in reflecting properties to five half-wave electric dipoles (i.e., the reflection was five times that of a tuned half-wave doublet oriented for maximum reflection).

Operating Heights Over Ground

In the case of a bomb approaching level ground at an angle, the first step in the calculation of height of function is to assume the earth to be an infinitely conducting plane. The signal reflected back to the bomb (which we shall call the driving antenna) is the same as that radiated by a mirror image of the bomb (or antenna) located as far below the conducting plane as the real bomb is above it. Thus, the field produced at the driving antenna by the image antenna is calculated in terms of current in the driving antenna, frequency, and geometry. To simplify the remainder of the derivation, the image antenna is now assumed to be a half-wave dipole and the voltage e induced in it by a given current in the driving antenna is calculated. Applying the reciprocity theorem, the same current at the center of the dipole gives the same induced voltage e at the feed-point of the driving antenna. Thus, the voltage induced in the driving antenna by the image dipole is found. If this voltage is multiplied by the ratio of the fields produced at the driving antenna by the image *antenna* and the image *dipole*, it will yield the true reflected voltage.

The field surrounding the antenna contains three components—the radiation field, the induction field, and the quasi-static field. For many practical purposes, only the radiation field need be considered. This simplifies the calculations and provides an easy working formula for determining operating heights. For the case of a bomb approaching ground at height h over terrain having a reflection coefficient n, the Doppler voltage detected by the fuze will be

$$e_R = \frac{knS}{h\beta_2}\phi(\theta) \text{ volts (root-mean-square)} \qquad (1)$$

where

S = the radio-frequency sensitivity of the fuze

k = a constant which is principally a function of the wavelength

$\beta_2 = \int_0^\pi \phi(\theta) \sin\theta d\theta$ (this expression may be computed readily by numerical integration)

θ = the angle of the major axis of the bomb with respect to the vertical

$\phi(\theta)$ = the directivity envelope (see Fig. 3).

Assume the input to the amplifier required to fire the thyratron is e_T volts (root-mean-square), measured at the Doppler frequency corresponding to the altitude at which the bomb is dropped.[3] Inserting this value in place of e_R in equation (1) yields the height of function

$$h = \frac{knS}{e_T\beta_2}\phi(\theta) \text{ feet.}$$

All of the time delays in the fuze system total less than five milliseconds, so that at normal operating ranges and speeds they can be neglected without appreciable error.

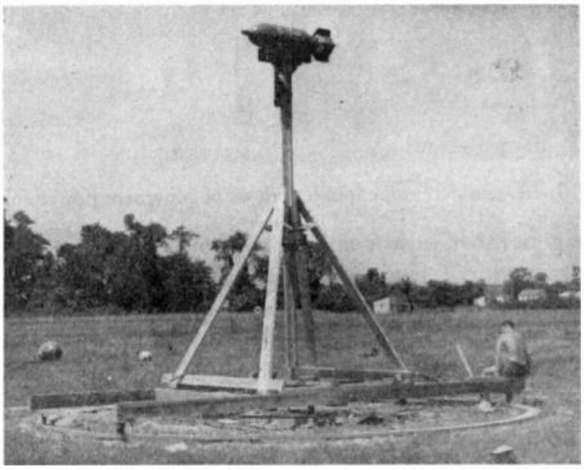

Fig. 6—Structure used for obtaining directivity envelope for proximity fuze.

A structure for obtaining a directivity envelope for a fuze mounted in a 500-pound bomb is shown in Fig. 6. Provision was made for continuous rotation of the structure. In the figure, the operator is reading the angular position on the ground protractor. The signal radiated by the fuze-bomb combination is picked up by a receiver located approximately 100 feet away. The intensity of the signal is measured for each angular position of the bomb.

The Power Supply

In addition to the requirements of small size and reliable operation at substratosphere temperatures (−40 degrees centigrade) and tropical conditions (+60 degrees centigrade, high humidity), the principal requirements which had to be met in the design of a universal type of power supply for the rocket, bomb and mortar applications were that it must have long shelf life and be a permanent part of the fuze, i.e., should not have to be assembled to the fuze in the field.

[3] Frequency = $2V/\lambda$ cycles per second. $V = \sqrt{2g \text{ (altitude)}}$ feet per second.

A careful study of all methods of power supply led to the selection of a wind-driven alternating-current generator with a suitable rectifier-filter system as the most practicable solution to the problem. Considerably more than the necessary power to operate such a device was available in the wind stream and, with proper mechanical design, could be harnessed without appreciably affecting the ballistics of the projectile. In fact, only a tiny fraction of the power available in the air stream was needed to supply the electrical energy for the fuze.

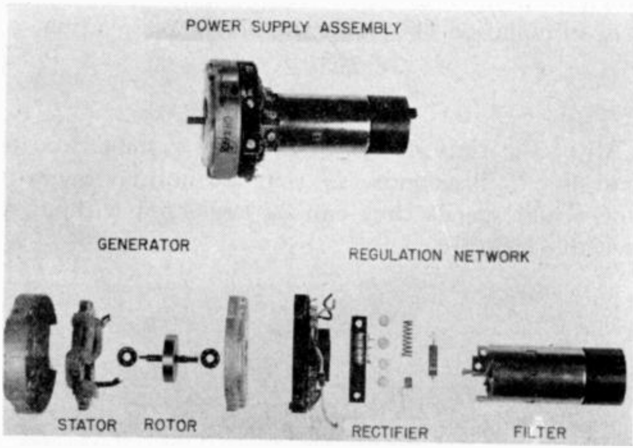

Fig. 7—Assembled and exploded views of generator power supply.

The generator power supply not only met the requirements outlined above, but provided the additional feature of an exceptionally safe method of arming the fuze, to be described later. One of the power supplies used in the bomb and rocket fuzes is shown both in assembled and exploded views in Fig. 7.

The alternating-current generator consisted of a six-pole magnet rotating within a stator carrying the coils in which the voltage is generated. The rotor of this alternator was a simple cylinder approximately one inch in diameter and one-fourth inch thick. Composed of Alnico, it was magnetized in production by simply inserting it in a six-pole magnetizing fixture and sending a brief pulse of unidirectional current through the six coils on the fixture. For the stator, either a standard six-coil, six-pole arrangement or a single-coil, six-pole winding, little used in modern practice but of a type described in literature dating back to 1896,[4] was employed. Separate windings were used for the A and B supply. C bias was obtained from the rectified B voltage.

By properly shaping the amplifier-gain versus frequency characteristic, it was possible to use alternating current directly on the filaments of all tubes. A bridge rectifier was used for the plate and bias supply and filtered by means of a simple resistance-capacitance filter, as shown in Fig. 8(a). An extra resistor (R_c) inserted at the low-potential side of the B output provided the necessary C voltage. This allowed the C voltage to be a definite fraction of the B voltage and to vary in the same manner as the B voltage. Thus, some compensation was provided for variations in B voltage from generator to generator in production.

[4] Edwin J. Houston, and A. E. Kennelly, "Electro-Dynamic Machinery for Continuous Currents," The W. J. Johnston Company, 1896, New York, N. Y.

Voltage Regulation

The large leakage reactance of the high-voltage winding was made use of in achieving excellent voltage regulation with speed. In the various projectiles employed, speeds ranged up to 125,000 revolutions per minute, the higher speeds occurring in the turbine models. With care in design, the top speeds could be reduced to less than 100,000 revolutions per minute, but the range was still large. The normal open-circuit voltage of this type of alternator increases almost linearly with speed. The obvious step in obtaining good regulation was to raise the voltage at low speeds by resonating the leakage inductance with an external condenser. This was the method adopted. Using the shunt regulation components R_1 and C_1, speed regulation characteristics similar to that of Fig. 8(b) were obtained. The plateau is reached at a speed below that at which the fuze is armed; that is, at which the fuze is ready to function electrically. The purpose of resistor R_1 was to broaden the resonance effect of C_1 and the generator leakage inductance, and thus limit the voltage at resonance to give constant voltage at all speeds above resonance.

By virtue of the inductive coupling between the A and B windings, the impedance reflected into the A voltage circuit, with the B regulation components and proper B load in place, was such as to provide an A-voltage speed-regulation curve similar to that of the B circuit.

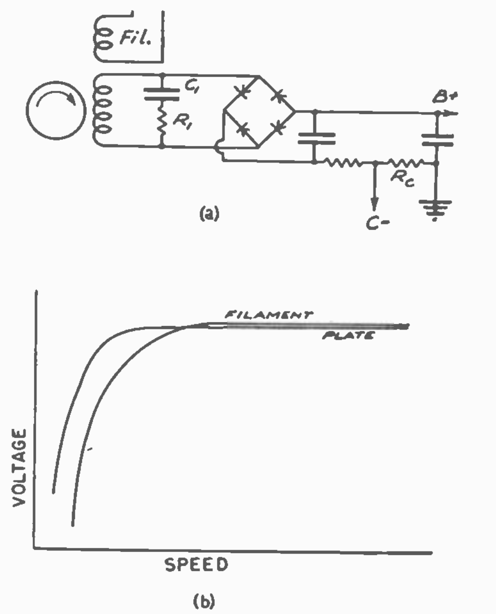

Fig. 8—(a) Rectifier and filter circuit for plate and bias power supply. (b) Speed versus voltage regulation characteristics.

Rectifier and Filter

Full-wave rectification was obtained by means of selenium rectifiers in the four arms of the bridge. In some applications, a voltage-doubler rectifier circuit was employed, allowing good performance with half the number of rectifier cells.

One of the important factors which helped to make possible the tiny generator-powered radio proximity fuze was the development of small selenium rectifiers. The rectifier itself, in one of the applications, was composed of ten cells, each about one-fourth inch in diameter.

Choice of the selenium rectifier was based on numerous considerations, including both the economical and the physical. Vacuum tubes would have provided a suitable solution to the problem of rectification; however, their cost and difficulties of production, including time, tools, and strategic materials needed, made it imperative that an inexpensive and easily produced substitute be found. Then, too, vacuum tubes draw filament power and in addition had to be made rugged. For example, in the trench-mortar application, the fuze is designed to withstand a setback force of 10,000 times that of gravity. This setback occurs as the shell is fired. Although the ruggedness necessary was accomplished in the design of the tubes, in order to obtain it special features of construction were necessary, with the attendant increase in cost and difficulty of production. It was felt that, wherever possible, substitutes for vacuum tubes would be desirable in a device of this type.

Both selenium and copper-oxide rectifiers were tested. The latter have especially desirable features and in the early stages of development appeared to be favorably adapted to the problem. In particular, they show a low reverse dynamic characteristic—that is, low conduction of current in the reverse direction. However, concentrated development on the selenium disk soon resulted in the obtaining of reverse characteristics which exceeded those of the copper-oxide rectifier. Also, the copper-oxide rectifier did not perform as well under the extreme ranges of temperature met in practice, especially at low temperatures, and full attention was soon focused on the selenium rectifier.

Method of Manufacture of Rectifier Cells

The exact method of manufacture of selenium cells is regarded as a trade secret. However, a general idea of the method may be told.

The cells are made on a base metal, such as steel, aluminum, etc. A large strip of metal is used and the individual cells are partially punched out, being held to the strip by 0.005-inch of metal which keeps the cells on that particular strip together throughout all the subsequent manufacturing procedure.

Selenium powder is applied to the strips, which are then baked under pressure at approximately 115 degrees centigrade. The strips are again put into an oven, this time without pressure, and held at a temperature of slightly over 200 degrees centigrade. Care is exercised, as this is very near the melting point of selenium. A shiny black appearance resulting from the first baking now changes to a crystalline grey. This practice is called annealing.

Following this, the cells are placed over a vapor of selenium dioxide. The material adhering to the selenium forms a thin layer and acts as a catalyst in the formation of the barrier layer. Finally, the counter-electrode is sprayed on, a mask being used to prevent a short circuit at the cell edges. The cells are now electroformed by connecting them to a source of direct-current voltage.

The assembly of rectifier cells in their containers, shown in Fig. 7, met rigid microphonics tests.

Mechanical Drive System

Impellers of both propeller and turbine type were employed, the former on rocket and bomb fuzes and the latter on the mortar and also on one of the rocket fuzes. The propeller type was either molded of bakelite or stamped out of steel. The turbine type was die cast. The pitch was selected at a value which gave the best compromise between fast starting and low top operating speeds.

The extremely high rotational speeds at which the generators were operated introduced severe mechanical problems. Even with the small degree of unbalance in early models, strong vibration resulted, and bearings were destroyed in a relatively short time. The introduction of commercial ball bearings in place of the sleeve bearings originally used gave a material improvement in performance.

The rotor, in addition to possessing excellent magnetic properties, required special metallurgical design to withstand the high speeds without tearing apart. Vanes were also balanced. End play in the rotating system was kept to minute figures hitherto thought impossible in small devices designed for very high production rates. For the higher generator speeds more attention was given to balancing of the rotating system, and operation was so much improved that it was possible to return to the use of sleeve bearings.

Safety and Arming

The radio proximity fuze, when armed, is sensitive to any sort of motion or action in its neighborhood which will change the amplitude of reflected waves (at a rate at which the amplifier is responsive). One may cause the fuze to operate by waving a bakelite rod close to it, or by touching two wires together at a considerable distance from the fuze. Touching a metal pipe or any other ground or metal object may change the reflected signal enough to fire the fuze. For this reason, exceptional care must be taken to see that the fuze circuits are not completed until the fuze is well away from the firing or release point. A fuzed bomb or rocket must be many hundreds of feet away from the plane or the ground firing point before there is any possibility of the fuze functioning. Several safety means are employed.

(1) A thick metal plate, usually called an interrupter plate, is interposed between elements of the explosive train so that if the electric detonator is discharged prematurely, the main explosive charge cannot be set off.

(2) The electric detonator is disconnected from the power circuit.

(3) With generator-powered fuzes, there is no power available to set off the detonator until the projectile is moving through the air at a high rate of speed.

Arming the fuze is accomplished through a gear train, driven by the same vane which drives the generator. Rotating the gear train removes the interrupter plate and connects the electric detonator. This occurs after the vane has made a preset number of revolutions corresponding to a fixed distance of air travel. The usual arming distance varies with type of projectile employed and may be as much as three or four thousand feet. Fig. 9 includes a breakdown of safety devices which, in the unit shown, are built into the power supply.

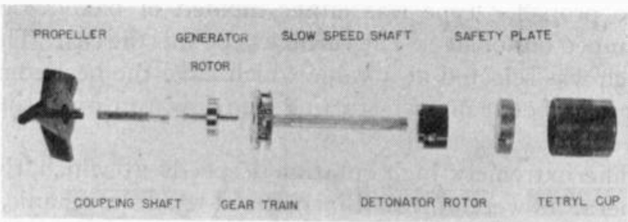

Fig. 9—Safety devices built into the power-supply assembly.

The detonator is set off-center in the detonator rotor, and its terminals are connected to contacts on the face of the rotor. When the fuze is not armed, the detonator is misaligned a number of degrees from a small hole in the interrupter plate. The hole is filled with tetryl, a material widely used in explosive train elements. The tetryl cup holds a larger charge of tetryl which is used to detonate the main explosive charge of the projectile. As the vane turns, the reduction gear train slowly turns the rotor by means of a slow-speed shaft. When the detonator is directly above the tetryl-filled hole in the plate, contact with the detonator leads is made; the rotor is released from the slow-speed shaft and locked in place, completing the arming of the fuze.

In using the bomb fuzes, an arming wire attached to the airplane is threaded through a metal pin on the fuze, which is arranged to block the fuze vane from turning. As the bomb is released the wire is withdrawn, the metal pin falls out, and the vane is free to turn and arm the fuze.

Rocket and mortar fuzes require other safety means. These fuzes have accelerating forces of from 10 to 10,000 times gravity at the moment of firing. Mechanical locks, which release the vane under the forces of acceleration, prevent arming of the fuze except when it is fired.

Tubes and Other Components

Much of the effort expended on radio fuzes was directed toward the development and procurement of small and rugged components. Chief among these were the tiny tubes, as no suitable tubes were available at the start of the war. Work was started with various tube manufacturers on improving the hearing-aid types of tubes, the initial steps being taken by the Navy shell-fuze development group of the Johns Hopkins Applied Physics Laboratory. Tube work on the Army phase of the fuze program at the same companies was directed primarily toward developing tubes free from microphonics in the presence of severe vibration.

Many new testing methods and procedures had to be developed, along with rigid manufacturing controls. As a result of this work, a very strong and stable line of inch-long tubes about 5/16 inch in major diameter were developed and produced in sufficient quantity to meet the heavy production requirements of the proximity fuzes. None of the production programs were ever delayed by lack of tubes.

For most of the other components, such as capacitors, resistors, and inductors, there was a continuous effort to reduce size and improve performance at extremes of temperature and humidity. Too much credit cannot be given to manufacturers of these items for the manner in which they engineered and produced the large quantities required.

Another important phase of the project was the development of suitable plastic materials for the nonmetallic parts of the fuzes. These parts included the nose cap, oscillator blocks, coil forms, and numerous housings for other components. Rigid mechanical requirements were imposed on the plastics by virtue of the severe strains to which the fuzes were subjected. In addition, those parts located in the high-frequency circuits had to have especially good electrical properties. These problems were solved by the close co-operation of plastics manufacturers.

Production and Laboratory Testing

Perfection is a prime requirement of ordnance items. A bombing mission may carry one or two dozen bombs in a round trip of as much as two thousand miles. Into the venture goes a bomber costing hundreds of thousands of dollars and a crew too valuable to reckon in money. For each fuze which fails to function, one bomb is lost to the mission and the whole mission may be jeopardized.

In order to assure the best possible fuze operation, a rigid system of production and field testing was instituted before release of the fuzes to the war theatres. Each fuze had to pass a comprehensive final test, and each subassembly was carefully checked prior to final assembly. Proper inspection on the line was of paramount importance. Usual production practices for electronic equipment could not be followed, for a device constructed to ordinary camera-model radio set specifications could hardly withstand firing in a rocket or mortar.

Special inspection agencies were set up by the Army Signal Corps or Army Ordnance Department in each area of production to further the rigid inspection system.

The assembly lines were either of the conveyor or the pass-along system. Every fifth or tenth operator was an inspector, and a defect in a subassembly could not go far without detection. After passing minute inspection, both mechanical and electrical, samples of units were selected from each lot produced and shipped to the National Bureau of Standards. There they were tested to exhaustion in the specially built Control Testing Laboratory. They were put through life tests, low and high temperature tests, temperature cycling from one extreme to another, humidity tests, salt-spray baths; and a very rude jolt test, after which they were required to perform properly. After packing in special hermetically sealed cans used for shipment overseas, the units were subjected to a packaging test. This was somewhat akin to being dropped off a truck and jostled around in every conceivable direction hundreds of times. Again the units were expected to perform properly after the test.

At the Control Testing Laboratory the sample units were disassembled and each subassembly and the principal components subjected to detailed analysis to determine potential sources of failure. Out of these tests came recommendations for improvement in design. A special production-engineering section was set up at the National Bureau of Standards to act as liaison between development groups, pilot production lines, control testing, and mass production plants. Valuable trade secrets were exchanged freely among manufacturers in the common interest.

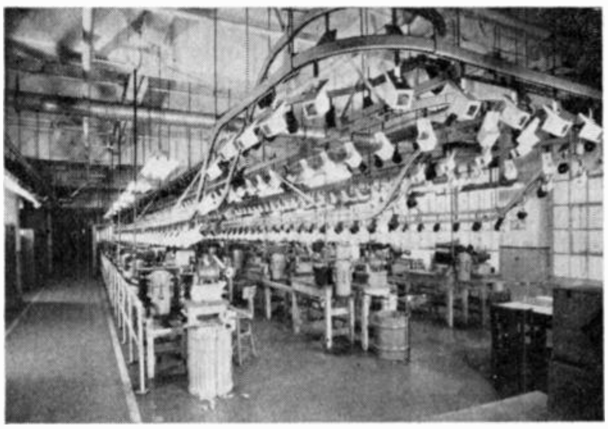

Fig. 10—Production line in a proximity-fuze plant.

The production line of one of the modern fuze plants is shown in Fig. 10.[5] This plant utilized an overhead conveyor system for passing units from the final assembly line to final test, thence into the packing room. A close-up of the conveyor system and a final test chamber is shown in Fig. 11. A fuze is within the chamber; the end of its power-supply assembly is seen projecting from the chamber face. A jet of high-pressure air drives the vane.

Throughout production, testing of completed fuzes remained the most pressing single problem, principally because of the difficulty of accurately simulating in a test fixture the actual conditions of a projectile in flight.

The final test chamber had to present both an electrical and a mechanical load to the unit. A dummy antenna was used to simulate the radiating body of the projectile. Mechanically, the fuze was screwed into a mount which simulated the mechanical condition when screwed into the nose of a bomb, rocket, or mortar. Thus mechanical resonances in the fuze were allowed to play their full part in generation of electrical noise. Not only was the electrical noise measured on final test, but other parameters of oscillator, amplifier, and power-supply performance were determined, with close "go" and "no-go" limits. In this manner, uniform operation in the field was assured.

[5] Courtesy of Emerson Radio and Phonograph Corporation.

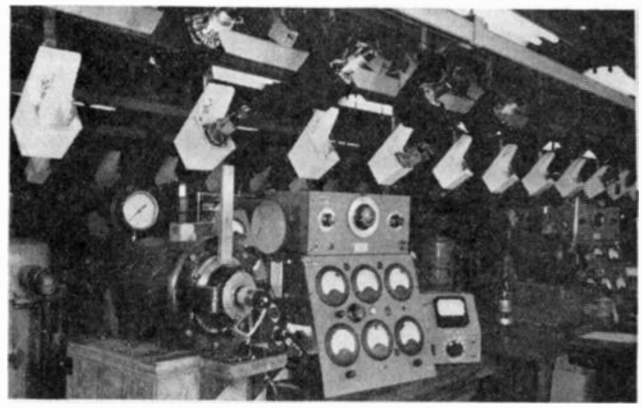

Fig. 11—Close-up of conveyor system and final test chamber.

Women operators were generally used to operate these stations. It is a distinct credit to them that they were by far the majority of the workers who built and tested these complex electromechanical devices.

A subassembly test station is shown in Fig. 12. This station was used to check the radio-frequency and audio-frequency performance of one type of bomb fuze. The fuze head is shown clamped in the reclining side of the cube-shaped metal box. With the side moved up in place so as to close the box, a radio-frequency load of approximately infinite impedance is presented to the oscillator. Any desired load may then be added by connecting a suitable radio-frequency resistor from the oscillator antenna lead to the side of the box.

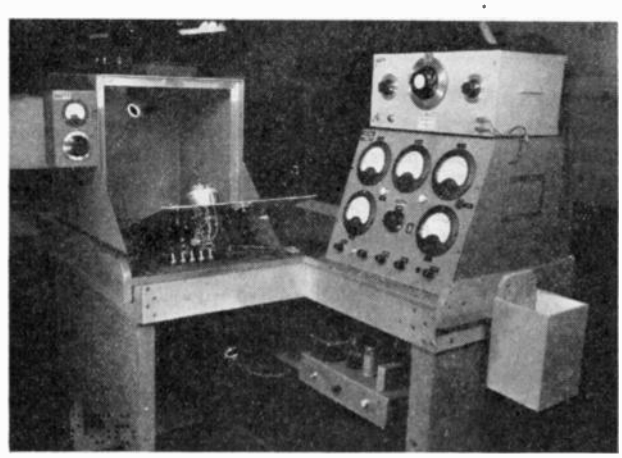

Fig. 12—Subassembly test station.

Field Testing

Before any lot of fuzes could be accepted for shipment to the field of action, a sample had to pass an ordnance proving-ground test. In the case of bomb fuzes, they were tested in bombs dropped over land or water. The height of function was measured, and the lot accepted if the units operated within specified limits. The height test was not the only test. Numerous safety tests with and without high explosives were made to assure proper operation of the arming and safety devices.

Interesting proving-ground tests of a fuze for the Army 4½-inch rocket were carried out at the National Bureau of Standards proving ground at Fort Fisher,

Fig. 13—Proximity-fuze proving ground, with rocket firing tower at left and a simulated bomber at right.

North Carolina, near Cape Fear. In the first tests at that station, an attempt was made to use aerial targets held aloft by small barrage balloons. Testing difficulties were many, for a radio fuze is sensitive to its departure from ground as well as to its approach to ground. Furthermore, early rocket projectors and aiming mechanisms were crude and did not permit accurate sighting on a target swaying in a wind. It was then realized that, if the projectile could be fired with its trajectory parallel to a plane surface, free-space conditions would be simulated and fixed range conditions could be established. Such an arrangement is shown in Fig. 13. The rocket firing tower is shown at the left and a simulated bomber at the right. The latter was made of plain chicken wire supported on four telephone poles. As the rockets were fired approximately horizontally, variations in the terrain between tower and target would produce undesired voltage ripples in the output of the amplifier. To eliminate this imperfection, the ground below was leveled off with a bulldozer. In this manner the fuze, which is insensitive to reflections of constant phase, was unaware of the fact that it was not traveling in free space. In Fig. 13, a puff may be seen below the corner of the left wing where a rocket with a radio proximity fuze fired on passing the target. Smoke puffs were used in place of high explosives in the rocket to indicate the point of burst and avoid replacing the target after each shot. On passing the target, the rocket continued on into the waters of the Atlantic Ocean, which may be seen on the horizon.

In a treatment of this type, only a glimpse may be had of the large amount of testing that was carried out on the radio fuzes in proving in the design and quality of manufacture and determining the performance in the field. Thousands of acceptance tests were made at many proving grounds in this country, and innumerable operational tests were made here, in England, and on the continent. Added to this was the valuable information yielded by the enemy, who so obligingly supplied targets for numerous tests under actual battle conditions

A Medium-Power Triode for 600 Megacyles*

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Summary—**An air-cooled triode, the L600E, was developed to produce a peak pulse power of 25 kilowatts at 600 megacycles for radar operation. The water-cooled 6C22 was then developed to provide higher efficiency in continuous-wave operation at that frequency. The construction and characteristics of these tubes are described. In an experimental crystal-controlled transmitter the 6C22 has delivered 500 watts at 600 megacycles.**

Introduction

THE LARGE peak power required by pulse radar systems demands vacuum tubes capable of delivering high peak emission currents at high voltages. The tubes usually are employed as oscillators, and the modulation, in the form of the pulses, is applied to the anode. The pulse is, thus, the envelope of several radio-frequency cycles. The radio frequency is determined by the oscillator circuit constants.

The high instantaneous voltages that exist during operation make it desirable to avoid spacing insulators between tube electrodes and to lengthen the external glass paths as much as possible. At the same time, rigidity of the electrode structure must be attained.

Interchangeability of tubes in any equipment is necessary and applies not only to the electrical characteristics, but to the physical mounting of the tube in the circuit as well.

In addition, the tubes must maintain their original characteristics and the available thermionic emission must not decay appreciably over long periods of operation. Satisfactory life requirements have been met in pulse radar tubes employing either thoriated-tungsten filaments or indirectly heated oxide-coated unipotential cathodes.

L600E

As radar development proceeded, it was evident that higher frequencies and powers had much to offer in increasing accuracy and range. Consequently, the development of a tube capable of delivering peak pulse powers

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of 25 kilowatts at 600 megacycles was undertaken in the latter part of 1941. After several designs had been made and tested, a developmental tube known as the L600E proved most promising. Technical information on this tube is given in Table I.

The L600E consists of a bifilar thoriated-tungsten-filament emitter with its electrical center brought out to a pin terminal, a squirrel-cage-type grid, and a reentrant copper anode with a bayonet ring at its lower end to provide a simple means for securing and positioning the tube in the socket.

With anode modulation in a concentric-line-type oscillator circuit, 25 kilowatts of peak power output could be produced at 600 megacycles by a single tube. In one application, using grid modulation, 7200 anode volts, and 1.62 pulses per second, each of 200 microseconds duration, 7.3 kilowatts of peak power were developed at 600 megacycles and 33 per cent efficiency.

In high-frequency tubes, transit-time effects must be seriously considered. By decreasing interelectrode clearances, the deleterious effects of the long time of electron travel compared with the period of the applied potentials are reduced. Transit-time effects are also decreased when high anode voltages are employed. Thus, a tube which may operate at a given high frequency with good efficiency under pulse conditions where high voltages are employed, may exhibit very low efficiency in continuous-wave operation at the same frequency because lower anode voltages must be employed.

TABLE I
CHARACTERISTICS OF L600E

Filament	Thoriated Tungsten
Filament volts	6
Filament amperes	13.5
Amplification factor	20
Mutual conductance (ma./volt, I_b=2 amperes, E_c= −100 volts)	10
Maximum anode volts (pulse)	25,000
Maximum anode dissipation (kilowatts)	0.3
Capacitances (μμf) C_{gp}	4
C_{gf}	5
C_{pf}	0.25

One result of transit-time effects is that not all electrons emitted by the filament or cathode when the grid is positive reach the anode. Many emitted electrons return to the cathode space-charge region. This causes a decrease in anode current and power output. To increase the anode current, the filament or cathode must supply a larger quantity of electrons to compensate for those electrons which do not reach the anode. It is obvious that the emission capabilities of the filament or cathode must be much greater in high-frequency applications than in low-frequency applications. The emission required may be several times as great as in low-frequency applications where transit-time effects are negligible.

6C22

While the L600E performed well as a pulse tube, it was unsatisfactory for continuous-wave operation. Employed as a continuous-wave oscillator in a concentric-line grid-separation circuit with 1000 anode volts, the efficiency at 600 megacycles was only 10 per cent, although at 300 megacycles the efficiency was 40 per cent. Consequently, a design formerly known as the L600N, now designated as the 6C22, was developed.

Construction

With the exception of the filament terminals and screw-type water jacket on the anode, the 6C22 is similar in outward appearance to the L600E. It is shown with the jacket in Fig. 1 and a sectional view appears in Fig. 2.

Fig. 1—6C22.

Internally, it differs dimensionally from the L600E. The filament-wire diameter is 25 per cent greater and the number of turns has been increased by approximately 35 per cent. The grid-filament and grid-anode clearances were reduced by approximately 60 per cent.

The result of this reduction in clearances and increased filament surface area was a much higher perveance and a lower amplification factor. The additional surface area increased the available thermionic emission.

Filament

The helical bifilar thoriated-tungsten filament is made of 0.025-inch-diameter wire and has an active emissive surface area of 3 square centimeters. The filament ends and center lead are terminated in monel-kovar cup assemblies sealed to a molded glass flare. This construction has the advantage of great mechanical strength and resistance to impact at the seals.

A shadowgraph comparator with a magnification of 10 times is used to inspect the filament for alignment of the turns to minimize unequal grid heating.

Grid

The grid is of the squirrel-cage type, consisting of 32 wires, 0.008 inch in diameter, spot-welded to and supported by a low-inductance cone. After completion, the grid is cold-stretched on the welding mandrel and then hot-stretched in vacuum on a special fixture to relieve all stresses and equalize the tension in the cage wires. In addition, this procedure assures equal heating and expansion of the grid in operation. The grid is then inspected on the shadowgraph comparator for wire straightness.

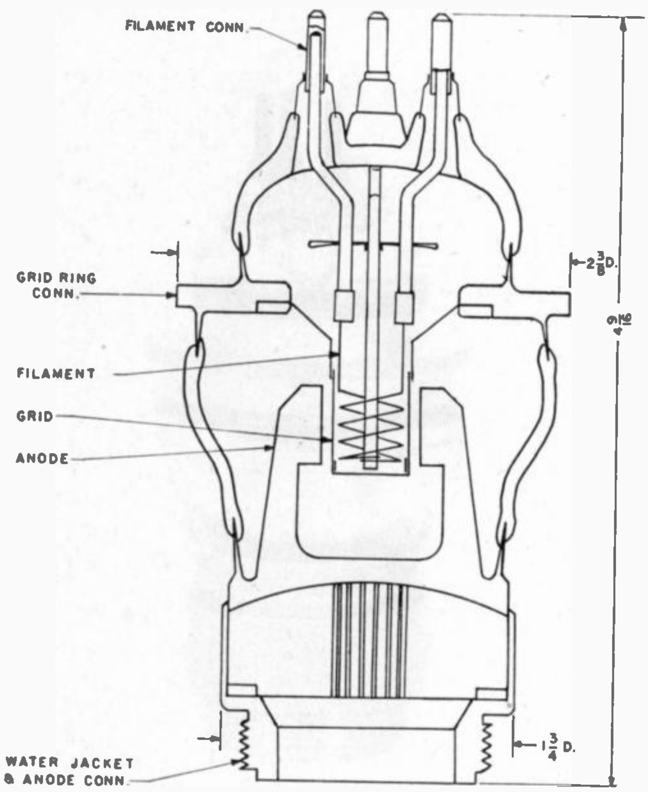

Fig. 2—Cross-sectional view of 6C22.

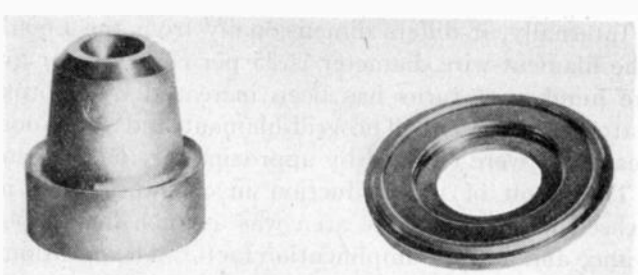

Fig. 3—Re-entrant anode and grid ring of 6C22.

Grid Ring and Anode

The grid ring and the anode are made of oxygen-free high-conductivity copper and lend themselves to fabrication by coining because of their unusual shape. The ring is coined from a washer 2¼ inches in outside diameter, 1 inch in inside diameter, and 3/16 inch thick. Under 250 tons pressure it assumes the shape shown in Fig. 3. The stubs are then trimmed so that they are 1/16 inch square, and the feather edges are formed from these stubs. The re-entrant anode is coined from 1-5/16-inch-diameter bar stock 2 inches long under 300 tons pressure to the shape shown in Fig. 3 and is then slotted on the water-jacket end. The feather edge is formed in the same manner as that of the grid ring, in a conventional machine lathe especially adapted for the purpose. The feather edges are carefully inspected for dimensions and flaws, after which the parts are cleaned and then glassed.

Assembly Procedure

The present bifilar filament is mounted on the tungsten leads of the molded flare, as shown in Fig. 4, and carburized. This assembly has the prebeaded grid ring sealed to it. Special fixtures are employed during this operation to assure axial and radial alignment of this ring with respect to the filament.

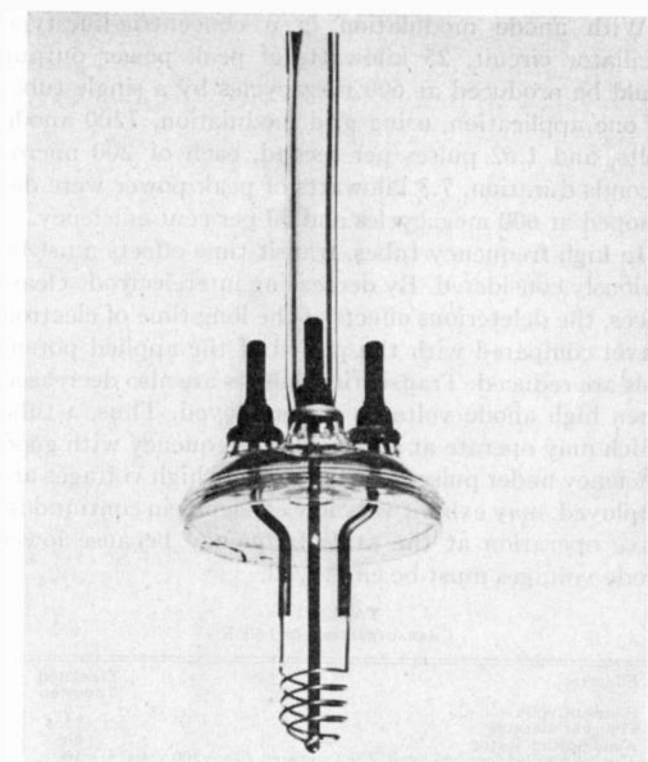

Fig. 4—Filament mounted on molded glass flare.

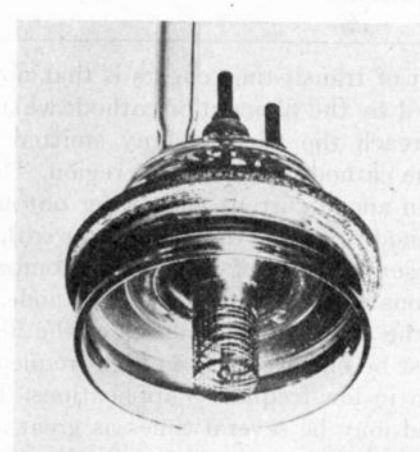

Fig. 5—Grid and filament assembly. The grid connecting ring and cone support may be clearly seen.

The grid is next assembled to its ring by means of a copper clamp ring and four flat-head steel screws. Before these screws are tightened, the grid is carefully aligned with the filament by again employing the shadowgraph. The resultant assembly is shown in Fig. 5.

The anode, with glass of proper length and shape already sealed to its feather edge, is now joined to the glass skirt on the grid connecting ring after careful alignment with respect to each other. This operation is shown in Fig. 6.

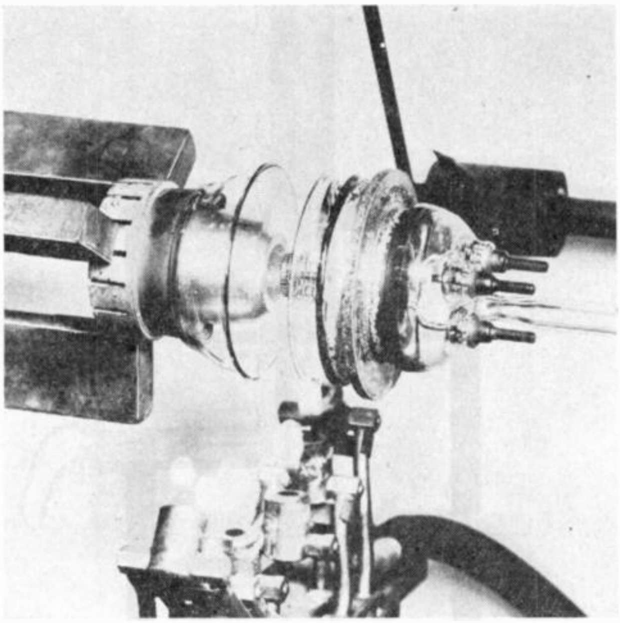

Fig. 6—The glass-mounted anode, held by the jaws of the lathe chuck, and the filament-grid assembly are joined at the two glass surfaces.

During all sealing operations, an atmosphere of nitrogen gas is employed to prevent oxidation of the tube parts.

Characteristics

As a result of the care used in making and assembling the electrodes, the electrical characteristics are very uniform. They are given in Table II.

TABLE II
CHARACTERISTICS OF 6C22

Filament	Thoriated Tungsten
Filament volts	6.5
Filament amperes	18
Amplification factor	9
Mutual conductance (ma./volt, I_b=3 amperes, E_c= −100 volts)	13
Maximum anode volts	3000
Maximum anode dissipation (kilowats)	2
Maximum grid dissipation (watts)	25
Capacitances ($\mu\mu$f) C_{fp}	6
C_{gf}	7
C_{pf}	0.4

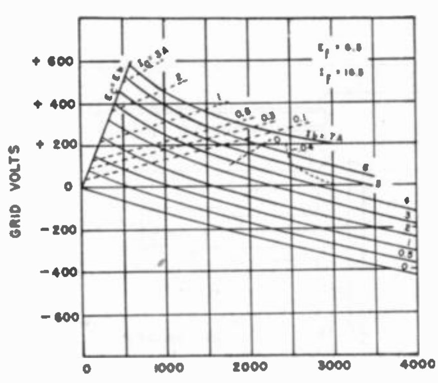

Fig. 7—Constant-current curves of the 6C22.

Constant-current curves are shown in Fig. 7. A typical curve of grid watts and primary grid current is shown in Fig. 8. A curve of current division between anode and

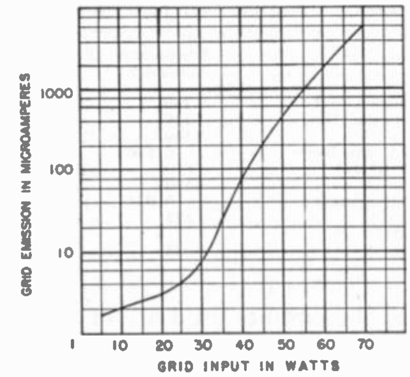

Fig. 8—Primary grid current plotted against grid input power.

grid for the same applied voltage on both electrodes is shown in Fig. 9. The average ratio of anode-to-grid current is 2.5 to 1.

A flow of water of 0.5 to 1 gallon per minute is necessary and sufficient to cool the tube in operation.

TESTS AND RESULTS

Typical operating conditions for oscillator and amplifier are shown in Table III.

TABLE III
TYPICAL EXPERIMENTAL OPERATION OF 6C22

	Oscillator	Neutralized Inverted Amplifier
Frequency (megacycles)	600	600
Anode direct volts	1200	1600
Anode direct current (amperes)	0.6	0.65
Anode power input (watts)	—	1040
Grid direct current (amperes)	0.050	—
Power output (watts)	250	500
Driving power (watts)	—	190
Power gain	—	2.6
Anode dissipation (watts)	470	—
Efficiency (per cent)	35	—

Most of the recent studies of this tube have been made at 600 megacycles with continuous-wave operation. At this frequency it has been studied as an oscillator and as a neutralized amplifier in a grid-separation circuit. It has also been operated successfully as a doubler in the range from 240 to 480 megacycles and as

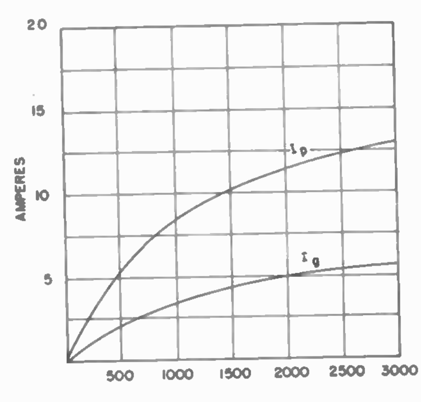

Fig. 9—Current division between anode and grid with the same voltage applied to both electrodes.

a tripler from 200 to 600 megacycles. The performance data under these operating conditions are given in Table IV.

TABLE IV
TYPICAL OPERATING CONDITIONS FOR 6C22

	Frequency Doubler	Frequency Doubler	Frequency Tripler
Input frequency (megacycles)	240	240	200
Output frequency (megacycles)	480	480	600
Anode direct volts	1500	1700	1100
Anode direct current (amperes)	0.540	0.640	0.275
Anode power input (watts)	810	1080	—
Grid direct volts	−430	−430	−400
Grid direct current (amperes)	0.025	0.025	0.020
Power output (watts)	285	360	100
Driving power (watts)	—	—	150
Efficiency (per cent)	35	33	33

In all cases, the circuits used are of the coaxial type to assure uniform current distribution and thereby reduce losses to a minimum. This is desirable in any case, but with the 6C22 it is particularly necessary to protect the grid seal from over-heating caused by high current concentration.

A diagrammatic view of a test oscillator using an air-cooled developmental version of the 6C22 known as the L600NR is shown in Fig. 10. A view of the experimental set-up with calorimeter load is shown in Fig. 11. Anode voltage and grid-bias voltage are brought in through quarter-wave chokes. The cathode circuit is piston-tuned, while the anode is adjusted for "half-wavelength" open-line operation. Radio-frequency output is coupled to the load by means of a capacitive pickup and matching section.

A hollow brass cylinder, connected at one end to the grid ring, open at the other end, and commonly termed a "grid bell," is adjustable in length, and serves to determine the amount and phase of feedback from output to input circuits.

Cooling air is brought to the anode through a dielectric pipe which extends into the inner region of the

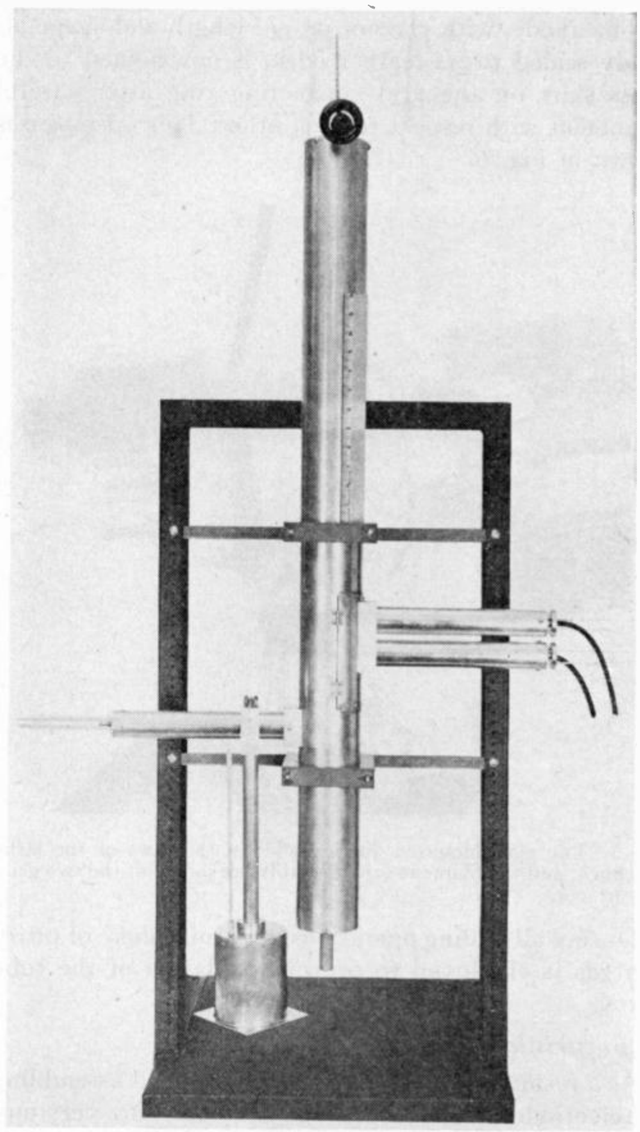

Fig. 11—Experimental setup of test oscillator with calorimeter load.

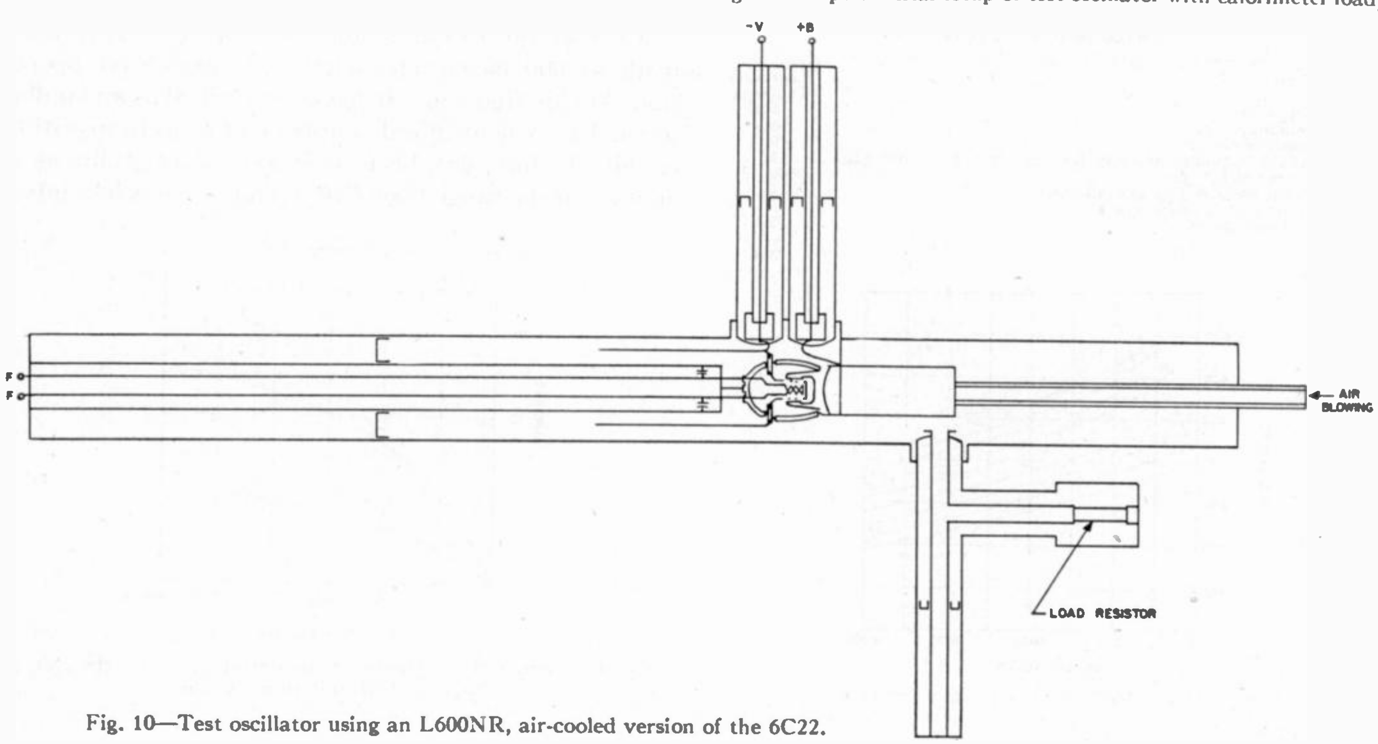

Fig. 10—Test oscillator using an L600NR, air-cooled version of the 6C22.

anode-line cylinder. In the case of the 6C22, which is liquid cooled, two dielectric pipes of small diameter are used.

When operated as a neutralized grounded-grid amplifier, results are obtained as given in Table III. Neutralization may be considered to have a twofold purpose. The first purpose is to reduce regeneration to prevent oscillation or to eliminate feedback through the tube entirely. The second purpose is to reduce interaction between the amplifier output circuit and its driving circuit to a minimum.

At lower frequencies these conditions can be satisfied simultaneously by the adjustment of a single parameter, because the output terminals of the driver and the input terminals to the active elements of the grid-cathode structure can be considered electrically identical. At ultra-high frequencies, where the impedance in the tube leads prevents access to the active tube electrodes, this simplification is no longer valid. Consequently, in general, two separate adjustments are required.

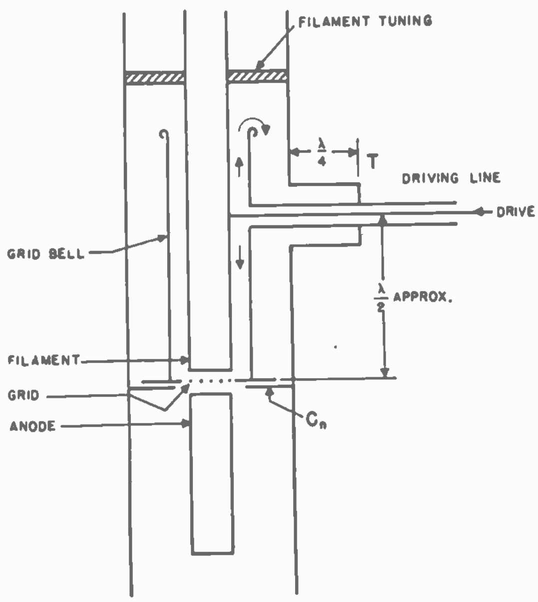

Fig. 12—Neutralization arrangement.

When these requirements, together with the desirability of coaxial-type structures, are taken into consideration, neutralization arrangements such as the example shown diagrammatically in Fig. 12 result. Here C_n is a comparatively large capacitance which permits a small amount of additional coupling between the input and output structures. Simultaneously, the length of the grid bell is adjusted so that the resulting feedback voltage is zero as determined by a null reading in a detector inserted in the driving line. In this manner, the two requirements for neutralization are satisfied.

The amplifier can deliver approximately 500 watts at 600 megacycles when driven either from a doubler or a tripler, or from another amplifier using the same type of tube. Fig. 13 shows a laboratory crystal-controlled transmitter delivering 500 watts at 600 megacycles. The cabinet on the left is an exciter with the following tube complement:

807 crystal oscillator and tripler (to 12.5 megacycles)
807 doubler (25 megacycles)
807 doubler (50 megacycles)
HK54 doubler (100 megacycles)
6C22 doubler (200 megacycles).

This exciter drives the 6C22 tripler, shown on the rack at the left, to deliver driving power to the 6C22 final amplifier (on rack at right) at 600 megacycles.

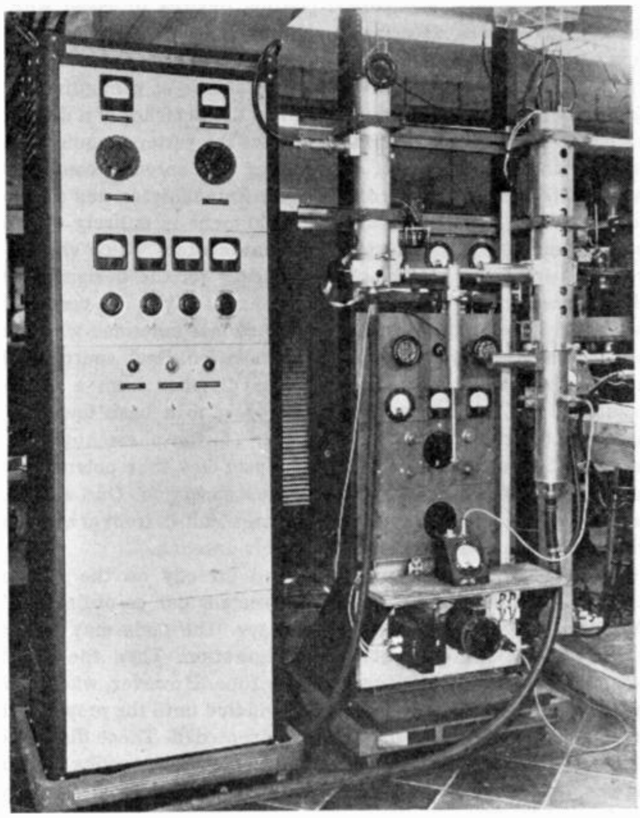

Fig. 13—Laboratory model of crystal-controlled transmitter delivering 500 watts at 600 megacycles. The excitor operates a 6C22 tripler at the left, which drives the final 6C22 amplifier at the right.

A neutralized water-cooled amplifier using a 6C22 has been grid-modulated satisfactorily in a television transmitter with video-frequency components up to 10 megacycles at a carrier frequency of approximately 500 megacycles. The synchronizing peak power output was 1 kilowatt.

Satisfactory life tests have been conducted on the 6C22 as a continuous-wave oscillator at 535 megacycles with 725 watts input, 35 per cent efficiency, for 500 hours.

Vibration tests in both the horizontal and vertical mounting positions show no failures up to 11 g, with 120 watts of filament and 20 watts of grid power applied during the test.

Acknowledgment

Acknowledgment is made of the contributions to this development by P. G. Chevigny, who originated the design of the tubes, and to G. Lehman for theoretical analysis of the tubes and circuits.

The RCA Antennalyzer—An Instrument Useful in the Design of Directional Antenna Systems*

GEORGE H. BROWN†, FELLOW, I.R.E., AND WENDELL C. MORRISON†, ASSOCIATE, I.R.E.

Summary—The equations for the radiation patterns of directional antenna systems are well known, but the arithmetical work necessary to secure a plot of the radiation pattern is tedious and time-consuming. Several mechanical plotting devices to assist with the problem have been described in the literature. A brief review of a few of these instruments is presented. These mechanical devices yield the radiation pattern for a given choice of configuration and antenna constants. In general, however, the designer of a directional antenna for broadcast-station use knows the pattern required and is faced with the problem of determining the antenna configuration which will yield this pattern. The RCA Antennalyzer was developed to synthesize or to analyze. The instrument is entirely electrical, with no moving parts except the potentiometers which change the various parameters. Developed specifically for the design of directional antennas for broadcast use, the Antennalyzer, as constructed, will yield the radiation pattern of directional antennas which have as many as five towers or sources of radiation. Each source is characterized by four parameters: (1) the distance from a reference point; (2) the azimuth angle with respect to a base line; (3) the amount of current in the antenna; and (4) the phase angle of this antenna current. Thus the Antennalyzer has four potentiometers associated with each antenna, with one exception. One antenna is located at the reference point and carries unit current at zero phase. Hence, no controls are required for this antenna.

The radiation pattern is displayed directly on the face of a cathode-ray tube, either in polar or rectangular co-ordinates. The Antennalyzer may be used in two ways. The dials may be set to correspond to a given antenna configuration. Then the resulting pattern is observed on the cathode-ray tube. However, when a given pattern is the goal, the dials may be twiddled until the proper pattern is obtained. Then the dial settings are recorded. These dial settings tell where to locate the towers, as well as the current ratios and phase angles to use. With a little practice, this operation of analysis may be performed in a few minutes.

Metering devices are included in the Antennalyzer so that the ratio of maximum field intensity to root-mean-square field intensity is obtained. Some of the unusual circuit details are discussed.

I. Introduction

THE EQUATIONS used to determine the radiation patterns of directional antenna systems are complicated in form, and numerical calculation from these equations is tedious indeed. Everest and Pritchett,[1] as well as Hutton and Pierce,[2] have described mechanical calculators which will plot the radiation pattern for either a two- or three-element array. The machines described by these authors are entirely mechanical, a fact which seems to limit the treatment to not more than three towers. Williams[3] uses some of the Hutton-Pierce Everest-Pritchett generating mechanisms in conjunction with a locked rotor transformer which has a three-phase primary and a single-phase secondary to produce an electromechanical calculator which handles up to five towers. There seems to be no fundamental limitation which would prevent the Williams apparatus from being extended to many more antennas. Williams obtains his results by a point-by-point method. Smith and Grove[4] have constructed a calculator identical in principle with the Williams apparatus, but have incorporated a recording mechanism so that a direct plot of the equation is obtained.

Any one of these machines should be of great assistance to the engineer who is occupied with the problem of designing directional antenna systems. It should be realized, however, that these mechanisms really perform the operation of synthesis. That is, for a given configuration of antennas, fed with prescribed currents, the calculators yield the resulting radiation pattern. As the need for more complicated patterns for broadcast stations increased, it became apparent to the writers and their associates that something more in the nature of an analyzer would be extremely helpful. Our goal then became the development of a calculator which would permit the operator to observe the radiation pattern at all times, with controls so flexible that the parameters could be changed at will while the operator watched the changing pattern. Thus we hoped to solve the problem of analysis by adjusting the controls until the desired pattern was obtained. Then the design parameters of the directional antenna system which produced this pattern could be read directly from the calibration scales on the control dials. Our endeavors along these lines have resulted in the instrument which we have chosen to call the RCA Antennalyzer. The instrument to be described in this paper is entirely electrical and electronic, with the resulting radiation pattern appearing on the face of a cathode-ray oscillograph.

II. An Analogy, the Basis for the Antennalyzer

The ability to produce this electrical instrument depended on the fact that an electrical equivalent to the radiation equation was recognized. Before proceeding with a description of this equivalence, we shall review briefly the radiation-pattern equation. In Fig. 1, we have two antennas or sources of radiation, one at a point marked A and the other at a point marked B.

* Decimal classification: R221. Original manuscript received by the Institute, March 8, 1946. Presented, Washington Section, Washington, D. C., September 9, 1945.

† RCA Laboratories, Princeton, N. J.

[1] F. Alston Everest and Wilson S. Prichett, "Horizontal-polar-pattern tracer for directional broadcast antennas," Proc. I.R.E., vol. 30, pp. 227–232; May, 1942.

[2] William G. Hutton and R. Morris Pierce, "A mechanical calculator for directional antenna patterns," Proc. I.R.E., vol. 30, pp. 233–236; May, 1942.

[3] H. Paul Williams, "A machine for calculating the polar diagram of an antenna," *Elec. Commun.*, no. 2, vol. 21, pp. 103–111; 1943.

[4] Carl E. Smith and Edward L. Gove, "An electromechanical calculator for directional antenna patterns," *Trans. A.I.E.E.* (*Elec. Eng.*, February, 1943) vol. 62, pp. 78–83; February, 1943.

The two antennas are considered to be identical. Antenna A is located at a reference point. We shall in this case use the east-west line through the reference point as a reference line. Then antenna B is located in the

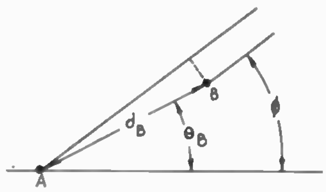

Fig. 1—Two antennas or radiating sources.

plane of the paper by a linear dimension d_B and an azimuth angle θ_B. The field, at a remote point which lies along a line having the azimuth angle ϕ, is then

$$\overline{F} = K\left(\overline{I}_A + \overline{I}_B \angle + \frac{2\pi d_B}{\lambda}\cos\left[\phi - \theta_B\right]\right) \quad (1)$$

where K is a constant which takes into account the height of the antenna as well as the distance to the measuring point. Since our calculator yields only the shape of the pattern, we need not concern ourselves with a detailed investigation of the nature of this constant. I_A is the current measured at some selected reference point in antenna A, while I_B is the current in antenna B measured at a corresponding reference point. The parameter λ is the free-space wavelength of the signal radiated from the antenna system. It may be observed that d_B/λ appears as parameter in the equation. Thus, we are free to measure the distances between antennas in terms of the operating wavelength.

We may then express the current in antenna B in terms of the current in antenna A.

$$\overline{I}_B = M_B \overline{I}_A \angle \alpha_B. \quad (2)$$

Substituting (2) in (1), we obtain

$$F = K\overline{I}_A\left\{1 + M_B \angle \left(\alpha_B + \frac{2\pi d_B}{\lambda}\cos\left[\phi - \theta_B\right]\right)\right\}$$

$$= K\overline{I}_A\left\{1 + M_B \cos\left(\alpha_B + \frac{2\pi d_B}{\lambda}\cos\left[\phi - \theta_B\right]\right)\right.$$

$$\left. + jM_B \sin\left(\alpha_B + \frac{2\pi d_B}{\lambda}\cos\left[\phi - \theta_B\right]\right)\right\}. \quad (3)$$

The absolute value of (3) is then

$$|F| = KI_A.$$

$$\sqrt{\left\{1 + M_B\cos\left(\alpha_B + \frac{2\pi d_B}{\lambda}\cos\left[\phi - \theta_B\right]\right)\right\}^2 + \left\{M_B\sin\left(\alpha_B + \frac{2\pi d_B}{\lambda}\cos\left[\phi - \theta_B\right]\right)\right\}^2}. \quad (4)$$

The radical is the term which determines the shape of the pattern and is the quantity which interests us. When five antennas are used, we may, as before, place antenna A at the reference point. In addition, we may locate each antenna by the distance from the reference point and the angle between the reference line and the line drawn from antenna A to the antenna in question. The shape of the radiation pattern is given by the relation

$$\sqrt{\begin{aligned}&\left\{1 + M_B\cos\left(\alpha_B + \frac{2\pi d_B}{\lambda}\cos\left[\phi - \theta_B\right]\right)\right.\\ &+ M_C\cos\left(\alpha_C + \frac{2\pi d_C}{\lambda}\cos\left[\phi - \theta_C\right]\right)\\ &+ M_D\cos\left(\alpha_D + \frac{2\pi d_D}{\lambda}\cos\left[\phi - \theta_D\right]\right)\\ &\left.+ M_E\cos\left(\alpha_E + \frac{2\pi d_E}{\lambda}\cos\left[\phi - \theta_E\right]\right)\right\}^2\\ &+ \left\{M_B\sin\left(\alpha_B + \frac{2\pi d_B}{\lambda}\cos\left[\phi - \theta_B\right]\right)\right.\\ &+ M_C\sin\left(\alpha_C + \frac{2\pi d_C}{\lambda}\cos\left[\phi - \theta_C\right]\right)\\ &+ M_D\sin\left(\alpha_D + \frac{2\pi d_D}{\lambda}\cos\left[\phi - \theta_D\right]\right)\\ &\left.+ M_E\sin\left(\alpha_E + \frac{2\pi d_E}{\lambda}\cos\left[\phi - \theta_E\right]\right)\right\}^2.\end{aligned}} \quad (5)$$

We shall now direct our attention to a set of electric-circuit equations. From a source we obtain an alternating voltage

$$e_A = E_A \sin(\omega t). \quad (6)$$

This is a simple alternating voltage, varying sinusoidally with time at a frequency f, where $\omega = 2\pi f$. To be specific, we obtain this voltage in the Antennalyzer from a crystal oscillator with a frequency of 100 kilocycles. A second voltage is obtained from this same oscillator; thus it has the same frequency. We shift this second voltage through a fixed phase angle α and, in addition, we phase-modulate this voltage. The equation of the second voltage is then

$$e_B = E_B \sin\left(\omega t + \alpha + k\cos\left[\omega_0 t - \theta\right]\right) \quad (7)$$

where k measures the amount of phase modulation in radians. The phase modulation is done with an alternating voltage of frequency f_o; hence $\omega_o = 2\pi f_o$. In the Antennalyzer, this frequency is 60 cycles. The 60-cycle source is phase-shifted through an angle θ degrees.

Equation (7) is easily expanded to give the following result:

$$e_B = E_B \cos(\alpha + k \cos[\omega_0 t - \theta]) \sin \omega t + E_B \sin(\alpha + k \cos[\omega_0 t - \theta]) \cos \omega t. \quad (8)$$

We may maintain the magnitude E_B at a fixed value relative to E_A, and let

$$M = E_B/E_A. \quad (9)$$

Substituting (9) in (8) and adding the result to (6), we obtain

$$e_A + e_B = E_A[\{1 + M \cos(\alpha + k \cos[\omega_0 t - \theta])\} \sin \omega t + \{M \sin(\alpha + k \cos[\omega_0 t - \theta])\} \cos \omega t. \quad (10)$$

Since the frequency f_o is small compared to the frequency f, we may use the following relation:

$$a \sin \omega t + b \cos \omega t = \sqrt{a^2 + b^2} \cdot \sin(\omega t + \tau) \quad (11)$$

where $\sqrt{a^2+b^2}$ is the equation of the envelope. Then the equation of the envelope of (10) is

$$\sqrt{\{1 + M \cos(\alpha + k \cos[\omega_0 t - \theta])\}^2 + \{M \sin(\alpha + k \cos[\omega_0 t - \theta])\}^2}. \quad (12)$$

A comparison of (12) with the radical of (4) reveals that the expressions are identical, with the correspondence of parameters shown in Table I.

TABLE I

Directional Antenna System	Electric Circuit of the Antennalyzer
Antenna current ratio M	Ratio of voltages M
Phase angle between antenna currents α	Radio-frequency phase angle α
Tower spacing $2\pi d/\lambda$	Phase-modulation angle k
Azimuth angle of tower θ	60-cycle phase shift θ
Azimuth angle of measuring point ϕ	Instantaneous angle of modulating voltage $\omega_0 t$

It may be observed that the correspondence between (4) and (12) is exact, so that the accuracy of calculation of the antenna patterns depends only on the degree of excellence with which we build our circuits. In the above detailed proof of the correspondence between the envelope of the combination of signals and the radiation pattern of a directional antenna system, we have limited the explanation to a two-element directional antenna. It is evident that we may add more terms similar to (7) to (10). The expansion from that point is straightforward. If five channels are used, it is seen that the envelope corresponds in form to (5).

If the signal described by (10) is put through a linear detector and the resulting output applied to the vertical deflection plates of a cathode-ray oscillograph, and a linear sweep signal synchronized with the 60-cycle source is applied to the horizontal deflection plates, we secure a plot of the radiation pattern in rectangular coordinates, with the angle ϕ as the abscissa.

III. CIRCUIT DETAILS

1. The Method of Securing Wide-Angle Phase Modulation

Early in the work on the Antennalyzer it was decided that a useful instrument should permit us to move any tower to a point at least $2\frac{1}{2}$ wavelengths from the reference point. This meant that we should be able to phase modulate through an angle of ±900 degrees; that is, the phase of the high-frequency sine wave should be advanced 900 degrees, brought back through zero phase, retarded 900 degrees, and finally returned to zero phase at a 60-cycle rate. A variety of phase-modulation schemes was considered and investigated. Because of inherent limitations or undue complexity, these various arrangements were discarded. It was not until the authors learned of a method of phase modulation which had been devised by Kell[5] for an entirely different application that it seemed desirable to proceed with the instrument.

The method due to Kell is illustrated by the sequence shown in Fig. 2. Here the top row shows the saw-tooth wave made from the 100-kilocycle sine wave obtained from the crystal oscillator. In row B the bottom part of the saw tooth is clipped off and discarded. It may be noted that the clipping level is different in each column. A fixed upper clipping level is then applied in row C, leaving the resulting pedestals as shown in row D. The width of the pedestals differs in each column, depending on the clipping level applied in row B. The pedestals of row D are then sent through a differentiating circuit to obtain the response shown in row E. Here the round positive pips are the result of the differentiation of the leading edge of the pedestals, while the sharp negative

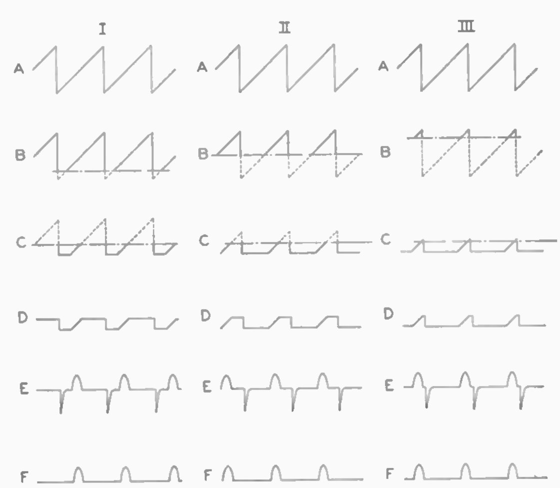

Fig. 2—The sequence of wave shapes used in securing wide-band phase modulation.

[5] Ray D. Kell, RCA Laboratories. United States Patent No. 2,061,734.

pips come from the straight back edge of the pedestals.[6] These latter negative pips, which hold their position with time at all clipping levels, are discarded. The rounded positive pips shift along the time axis linearly with clipping level, as shown in row F. These impulses are next applied to the grid of a tube which has a circuit tuned to 100 kilocycles in its plate lead. Here the train of pips is changed to a continuous sine wave again. The phase of this sine wave is thus controlled by the clipping level. The phase is then varied at a 60-cycle rate, giving the desired phase modulation. The amount of swing depends upon the magnitude of the 60-cycle voltage applied. The fixed phase shift of the antenna currents is secured by applying a direct-current bias in series with the 60-cycle voltage.

An examination of Fig. 2 shows that, for ideal and perfect formation of the saw tooth as well as the differentiation, we might secure total phase shifts of almost 360 degrees; that is ±180 degrees. Since we superimpose the fixed phase angle of the antenna currents on the swing of 900 degrees to take care of maximum tower spacing, we must secure a swing in either direction of 1080 degrees. We have chosen to provide a swing in either direction of only 120 degrees. Then the 100-kilocycle signal is passed through a frequency-tripling stage to raise the frequency to 300 kilocycles as well as to multiply the phase shift by three. This is followed by another tripling stage, so that the signal emerges with a frequency of 900 kilocycles and with nine times the phase deviation secured at the initial frequency.

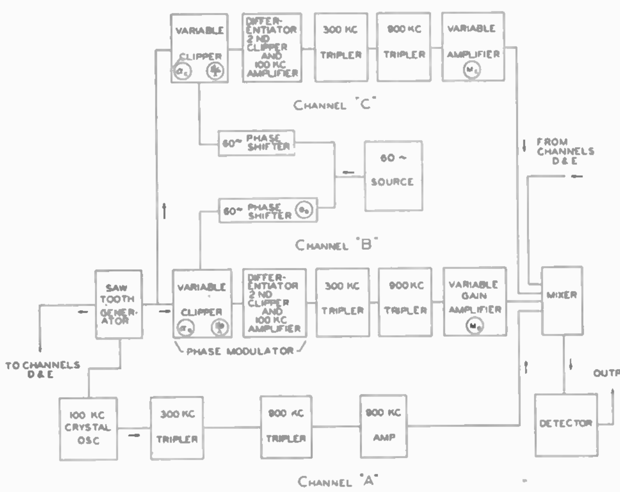

Fig. 3—Block diagram of the RCA Antennalyzer.

2. *The Complete Antennalyzer*

A block diagram of the Antennalyzer incorporating the Kell system of phase modulation is shown in Fig. 3. Since antenna *A* is placed at the reference point and is considered to carry a current of unit amplitude and zero phase, no controls need be provided for this antenna. Therefore, the 100-kilocycle signal is simply tripled twice in frequency and amplified before feeding into the mixer tube. The 60-cycle voltage is fed into the other four antenna channels through individual phase shifters, with an individual control of magnitude of the 60-cycle voltage provided directly after each phase shifter. The phase shift of the 60-cycle voltage is accomplished by means of three potentiometers ganged together and arranged in capacity-loaded transformer circuits to secure a total possible shift of 360 degrees. These controls locate the towers as far as azimuth position is concerned. The magnitude controls of the 60-cycle voltage vary the tower spacings; that is, the magnitudes of the phase swings of the high-frequency signals.

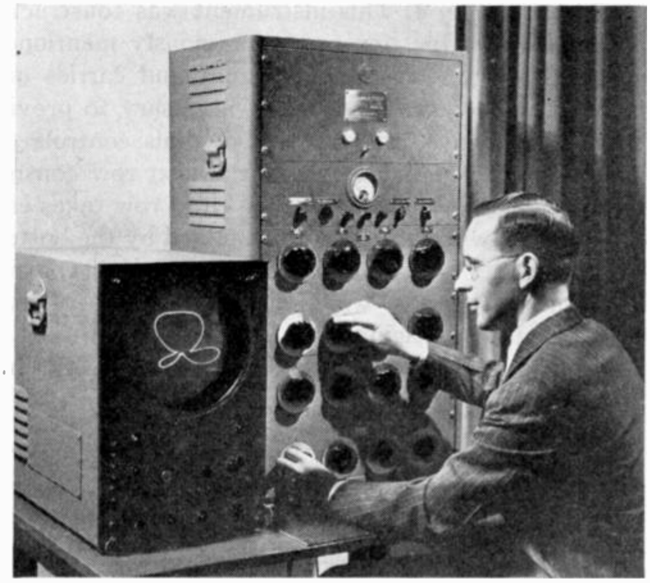

Fig. 4—The RCA Antennalyzer.

As stated above, the phase angle of the antenna currents is controlled by adding a fixed bias in series with the 60-cycle voltage into the clipper tubes. The variable-gain amplifiers used just ahead of the mixer tube are controlled by bias from suitable potentiometers, thus providing control of the current ratios of the antenna currents. In this fashion, we have been able to control all parameters by means of potentiometers which carry either direct or 60-cycle voltages. It is this ability to secure easy change of controls that makes the instrument so very flexible.

The 900-kilocycle signal passes from the mixer tube to a linear detector. Here the signal is rectified, and a signal which corresponds to the envelope of the high-frequency signal passes to the oscillograph where the pattern is displayed in rectangular co-ordinates. The RCA 327-A oscillograph is directly coupled to give a response to direct voltages. This is necessary to successful operation of the Antennalyzer, since without the direct-current response we would find the pattern shifting to equalize itself about the normal zero axis.

[6] It is possible to obtain wave shapes which very closely approximate those drawn in Fig. 2(A, B, C, and D). If the leading edges of the pedestals of Fig. 2-D were differentiated perfectly, the positive pip of Fig. 2-E would be perfectly flat-topped. The stray capacitances of the circuits result in the rounded positive pips shown in Fig. 2-E. Since only the fundamental of this response is used in our later operations, it is not important to secure better differentiation.

With direct-current response, we always find the pattern in the proper relative position with respect to the zero axis. For example, when only antenna A is used the antenna system is omnidirectional, and we have only direct current coming out of the detector. With the oscillograph which responds to direct current we find the trace correctly displaced from the zero axis. If the oscillograph were of the conventional type, the trace would coincide with the zero axis.

The completed Antennalyzer and the oscilloscope are shown in Fig. 4. This instrument was constructed to take care of five towers. As previously mentioned, antenna A is at the reference point and carries unit current at zero phase, so it is not necessary to provide controls. In Fig. 4, the top row of dials controls the parameters of antenna B, while the next row controls the parameters of antenna C. The third row takes care of antenna D, while antenna E is handled by the bottom row. The column of dials on the extreme left controls the azimuth angles θ, while the next column of dials varies the tower spacings d/λ. The column of dials on the extreme right controls the current ratios M, while the next column handles the phase angles α.

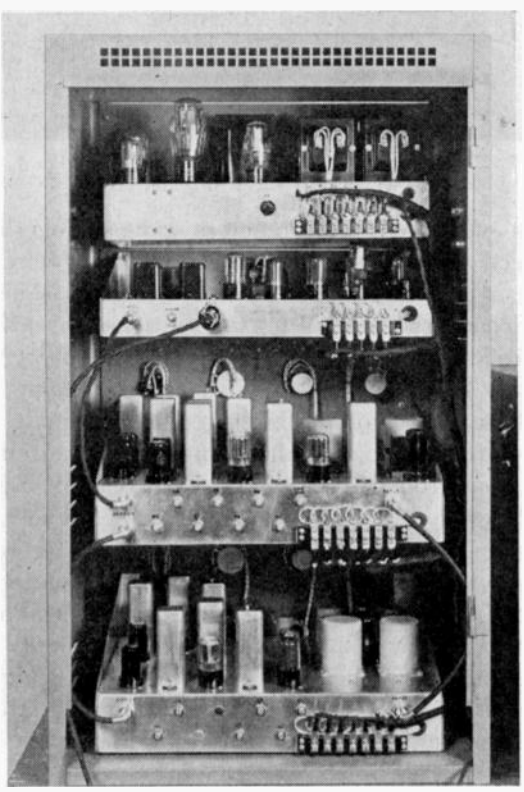

Fig. 5—A rear view of the Antennalyzer.

A rear view of the Antennalyzer is shown in Fig. 5. Fifty-two vacuum tubes of various types are used in the Antennalyzer to perform a variety of functions.

3. *Displaying the Pattern in Polar Co-ordinates*

To display the pattern in rectangular co-ordinates is by far the simplest procedure. However, many engineers are used to looking at the patterns plotted in polar co-ordinates. To provide a polar pattern, the circuit of Fig. 6 was constructed.

At first glance, one might expect to use the output of the Antennalyzer with suitable phase shifters to secure the polar trace. It should be remembered that the output contains direct current in addition to a 60-cycle component, as well as numerous harmonics of the 60-cycle voltage. Again returning to the simple example of a single tower, we wish to secure a circle on the oscilloscope with only direct current coming out of the Antennalyzer.

In Fig. 6 sine waves of voltage with a frequency of 60 cycles come in at the left. Since these are pure sine

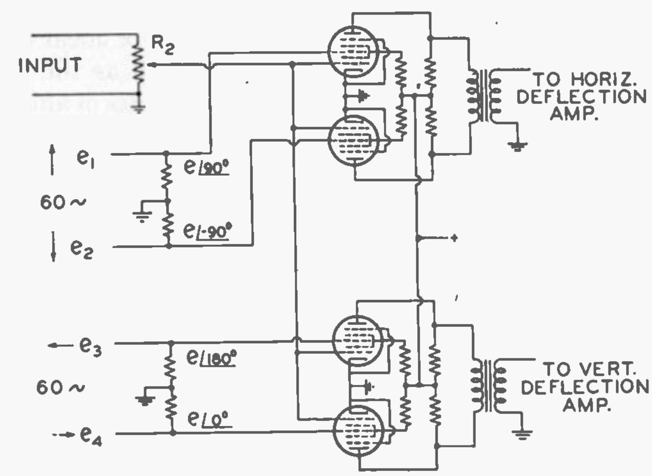

Fig. 6—The circuit used to give a polar plot.

waves, one pair of voltages is shifted 90 degrees in phase from the other pair by means of a simple resistance-capacitance circuit. The pairs of tubes are fed in push-pull by these voltages and the output circuits are arranged in push-pull. Then, with one output voltage fed to the vertical deflection plates and the other output voltage fed to the horizontal deflection plates and shifted 90 degrees in phase, a circular trace is obtained on the cathode-ray tube when no signal comes in from the Antennalyzer. In this condition, the tubes are biased to cutoff. If the tube characteristics were linear with sharp cutoff, we should then secure a point on the oscilloscope. The output of the Antennalyzer is fed to the resistor R_2 at the upper left-hand corner of Fig. 6. This resistor then feeds the pairs of tubes in parallel. With good balance, no signal from the Antennalyzer appears in the output circuits. This signal merely serves to control the characteristics of the tubes in a way that resembles modulator action. Because cutoff is not perfect and because the linearity and balance differ from the ideal, the trace which we secure on the oscilloscope is not perfect enough for computing purposes. No great effort has been made to improve the polar co-ordinate display since it was felt that, even with a perfect polar plot, information in the region of the null points would be hard to obtain. Consequently, more effort has been put on securing higher accuracy in the rectangular co-ordinate system. The justification for this reasoning will be displayed in the following discussion.

4. Measuring the Gain of a Directional Antenna System

When the designer has arrived at a pattern of the proper shape, he usually desires a knowledge of the scale factor to place on the plot. An exact determination involves a knowledge of the mutual resistances existing between the antennas.[7] However, an approximate answer may be obtained quickly by plotting the pattern in polar co-ordinates and measuring the area of the pattern with a planimeter. A circle whose area is the same is then taken as the circle from a single antenna operated with the same power. The radius of this circle is the root-mean-square value of the horizontal polar diagram. This approximate relation may be obtained by measuring the peak value of the signal coming out of the Antennalyzer and then measuring the root-mean-square value of the same signal. The instrument panel used for this purpose may be seen near the top of the Antennalyzer shown in Fig. 4. The circuit used is given by Fig. 7. The signal from the Antennalyzer is fed to the input terminals shown in the upper left-hand corner of Fig. 7. First the signal is fed to the peak-reading volt-

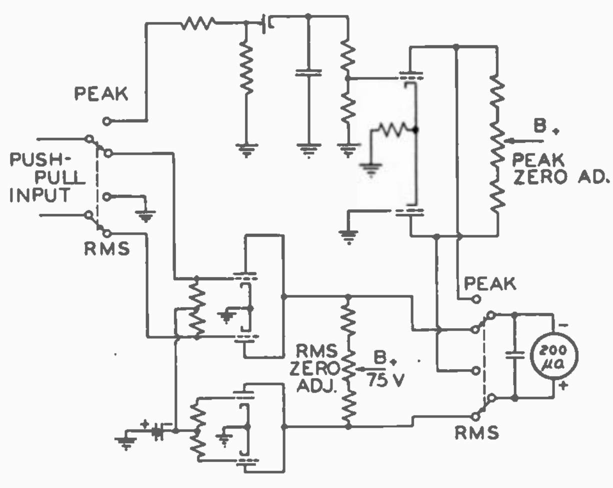

Fig. 7—The peak-root-mean-square voltmeter circuit.

meter, which consists essentially of a diode rectifier. The input signal is adjusted until the meter in the output reads full scale. Then the signal is switched to the input of the root-mean-square voltmeter. The output meter is switched to this voltmeter at the same time. Since the meter scale is calibrated with full scale equal to unity, the new reading is now the ratio of the root-mean-square signal to the peak signal.

The root-mean-square voltmeter is a square-law device. Since the output of the Antennalyzer contains a direct-current component as well as alternating-current terms, cross-product terms not properly included in the determination of the root-mean-square of the pattern are brought into the reading unless the complex circuit with push-pull input and push-push output is used.

[7] George H. Brown, "Directional antennas," Proc. I.R.E., vol. 25, pp. 78–145 (equation (49)); January, 1937.

IV. The Antennalyzer in Operation

The calibration of the instrument is readily accomplished. First, all antennas are turned off except for antenna *A*. In rectangular co-ordinates, this source then

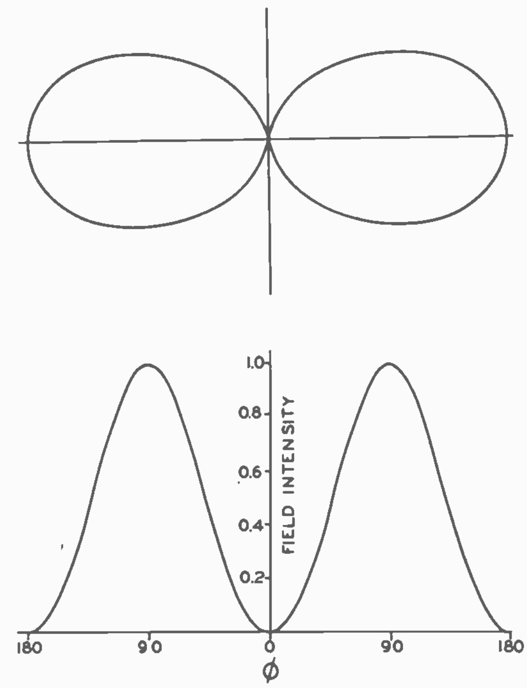

Fig. 8—Horizontal radiation patterns of two antennas. $M_B=1$; $\alpha_B=0$ degrees; $d_B/\lambda=0.5$.

gives a straight horizontal line, displaced from the zero axis. Then the spacing control for antenna *B* is set to zero. This places antenna *B* so it coincides with antenna *A*. The current-ratio dial for antenna *B* is turned on and the current ratio and phase angle adjusted simultaneously until the horizontal line has reached a minimum position which should coincide with the zero axis. This means that the current in antenna *B* is exactly equal and 180 degrees out of phase with the current in antenna *A*. This adjustment then establishes the unity value point on the current-ratio dial, and locates the 180-degree point on the phase-angle dial. The phase-angle dial is then turned until maximum displacement is found for the horizontal line. This procedure locates the zero-degree point on the phase-angle dial. Next, with antenna *B* set at unit current and zero phase, the spacing dial is turned until a "figure 8" pattern with the minimums just reaching zero is obtained. This establishes the half-wave-spacing point on the dial. The calibration of the tower azimuth angle is easily obtained by turning this dial and suitably marking the dial as the pattern is marched across the scale. Reference to a chart of patterns obtained with two towers assists in cross-checking quickly a number of calibration points.[8]

In Fig. 5, a number of vernier controls may be seen. For each main dial, there is a vernier on the back so that a check and adjustment on the calibration may be made at any time.

Fig. 8 shows a calculated polar diagram for two towers carrying equal and in-phase currents, when the tower spacing is one-half wavelength. This field pattern plotted in rectangular co-ordinates is also shown in the same illustration. The increase in detail of the display in rectangular co-ordinates is evident. Fig. 9 shows the trace on the Antennalyzer for the same set of conditions. Fig. 10 shows the calculated polar and rectangular trace

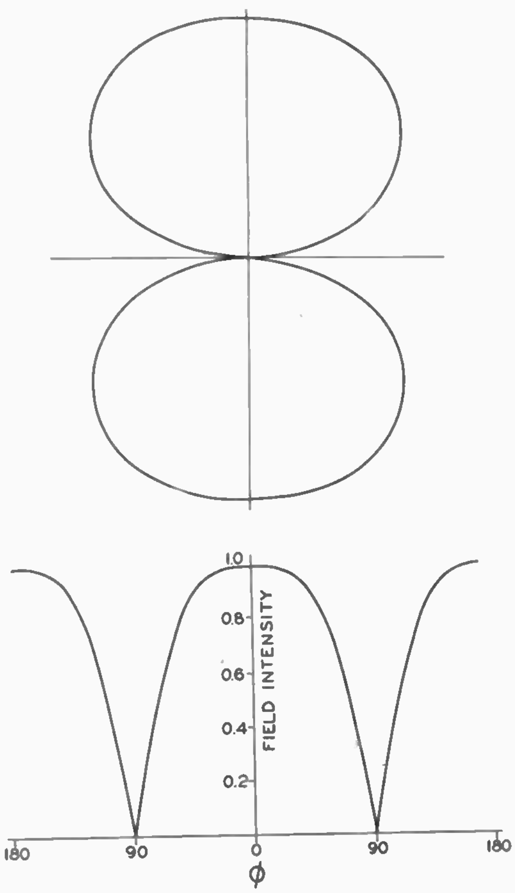

Fig. 10—Horizontal radiation patterns of two antennas. $M_B=1$; $\alpha_B=180$ degrees; $d_B/\lambda=0.5$.

for the same conditions as Fig. 8, except that the two currents are now 180 degrees apart in phase. Fig. 11 is the corresponding trace shown on the Antennalyzer. The polar plots of Figs. 8 and 10 fail to show the marked difference in behavior in the null points that are shown by rectangular traces.

Fig. 12 shows the configuration of antennas installed at Station WTAR, Norfolk, Virginia, several years ago.

[8] See Fig. 15 of footnote reference 7.

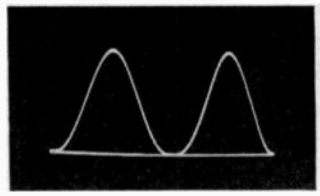

Fig. 9—The Antennalyzer trace for the conditions shown in Fig. 8.

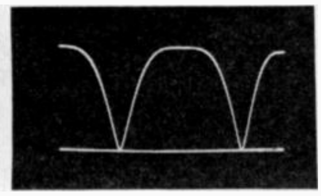

Fig. 11—The Antennalyzer trace for the conditions shown in Fig. 10.

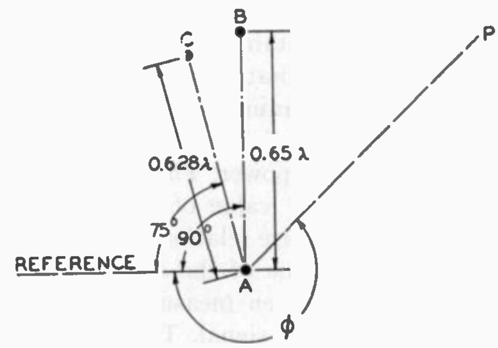

Fig. 12—The configuration of antennas used at WTAR, Norfolk, Virginia.

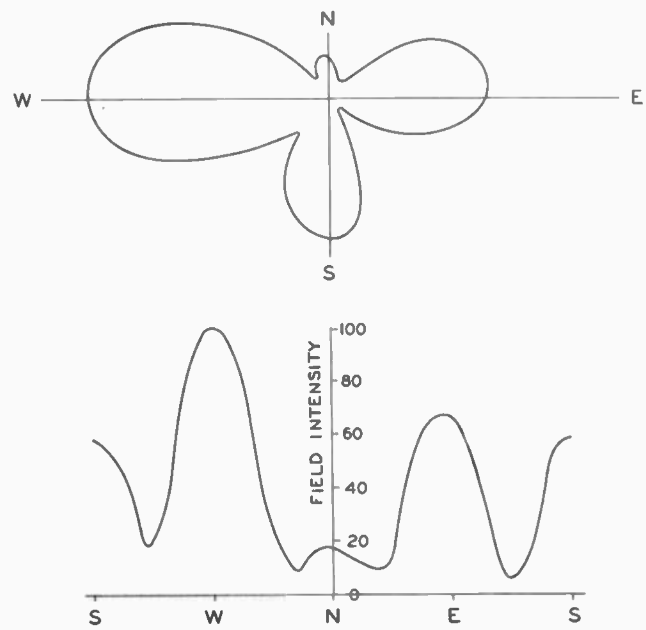

Fig. 13—The horizontal pattern of the WTAR array, plotted in both polar and rectangular co-ordinates.

The calculated horizontal radiation pattern is shown in Fig. 13, plotted in both polar and rectangular co-ordinates. The corresponding polar plot shown on the Antennalyzer is reproduced in Fig. 14, while Fig. 15 shows the same plot in rectangular co-ordinates.

In connection with the array shown in Fig. 12, the writers tried an experiment to see how much skill was required in the manipulation. The trace taken from Fig. 13 was marked on the face of the oscilloscope with crayon. Then the services of an engineer who was entirely unfamiliar with the Antennalyzer were enlisted. In six minutes, he had manipulated the dials until the trace on the oscilloscope coincided with the crayon markings. He had, however, arrived at an antenna arrangement which differed from that shown in Fig. 12. It has been found that where a rather complicated pattern is desired, making necessary the use of three or more antennas, it is possible to find two or three configurations which all yield the same pattern.

It is interesting and instructive to spend some time varying the numerous controls at random to see the wide variety of patterns which may be obtained with combinations of three, four, and five antennas.

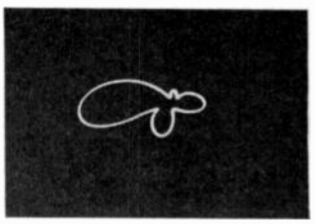

Fig. 14—The polar plot obtained from the Antennalyzer for the WTAR array.

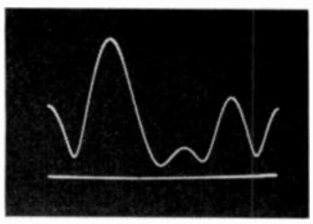

Fig. 15—The rectangular coordinate plot on the Antennalyzer for the WTAR array.

The writers have used the Antennalyzer to assist other engineers in the design of a number of directional antennas for broadcast use. This experience leads us to believe that the instrument is a valuable tool which removes most of the tedium from this wearisome problem. It is, of course, still necessary to calculate the final pattern, using the parameters established by the Antennalyzer, when extremely accurate results are desired. In fact, it is sometimes necessary to vary the parameters slightly and make several calculations. In spite of this bit of work, the Antennalyzer quite evidently reduces the time required for the problem from several days or even weeks to a few hours.

V. Calculation of Vertical Patterns

In the previous discussion, we have talked only of radiation patterns in the horizontal plane. Equation (4) was restricted to this case. However, the Antennalyzer may be used readily to calculate vertical radiation patterns as well. If the point at which the field intensity is reckoned lies in space above the horizontal plane, and a line drawn from the base of antenna A to the measuring point makes an angle β with the horizontal plane, the quantity in (4) which establishes the shape of the pattern becomes

$$f(\beta)\sqrt{\left\{1 + M_B \cos\left(\alpha_B + \frac{2\pi d_B}{\lambda}\cos[\phi-\theta_B]\cos\beta\right)\right\}^2 + \left\{M_B \sin\left(\alpha_B + \frac{2\pi d_B}{\lambda}\cos[\phi-\theta_B]\cos\beta\right)\right\}^2}. \quad (13)$$

The quantity $f(\beta)$ in front of the radical is the vertical radiation pattern of a single antenna.[9] If the antennas are very short, $f(\beta)$ becomes simply $\cos\beta$. When the antennas are each one-quarter wave tall,

$$f(\beta) = \cos\left(\frac{\pi}{2}\sin\beta\right)\bigg/\cos\beta.$$

To calculate the vertical pattern of a directional antenna from (13), we choose a value of ϕ and substitute numerous values for β. With the Antennalyzer, we first choose the angle ϕ. Then, with θ_B known, we find a quantity $(d_B/\lambda)\cdot\cos[\phi-\theta_B]$ and set the spacing dial to correspond to this new value. If more than two antennas are used, we make this calculation for each antenna and set the proper spacing dial to the new value. We next set all the azimuth or θ dials to zero. Then a plot of the radical shown in (13) is shown on the oscilloscope. We have not yet been able to devise a means of multiplying this radical by the quantity $f(\beta)$, so it is necessary to multiply the pattern by the proper $f(\beta)$ after the curve has been replotted on graph paper.

Another method of studying the vertical characteristics is to determine the way the pattern changes as ϕ changes through 360 degrees, at a given elevation angle. This plot might be termed the horizontal radiation pattern at a fixed elevation angle. We first choose a value of β. Then each tower spacing is multiplied by $\cos\beta$ to determine a new setting for each spacing dial. With the θ dials set at the true values, the trace on the oscilloscope is the radical of (13) as a function of ϕ. Again it is necessary to multiply the resulting trace by $f(\beta)$.

VI. Conclusion

A directional-antenna pattern calculator has been described which performs the functions of analysis and synthesis, and which handles arrays with as many as five antennas. No fundamental circuit relations prevent the extension to many more antennas. The instrument was limited to five antennas because it was felt that this number would take care of most broadcast-antenna problems.

[9] George H. Brown, "A critical study of the characteristics of broadcast antennas as affected by antenna current distribution," Proc. I.R.E., vol. 24, pp. 48–81; January, 1936.

Electroencephalographic Technique from an Engineer's Point of View*

WALTER G. EGAN†, ASSOCIATE MEMBER, I.R.E.

Summary—**A fairly recent medical usage of electronic equipment is in the recording of the electrical activity of the brain. High-gain, high-fidelity amplifying equipment is used to record 50-microvolt, 2- to 40-cycle-per-second impulses from the brain. A brief summary of interpretation is made, particularly in reference to artifact. A new type of electrode is described which fulfills the criteria for good leads. Suggestions on the improvement of existing equipment are made, such as to improve calibration accuracy and recorder performance.**

THE word electroencephalograph is derived from the Greek words ἤλεκτρον, meaning amber, ἐγκέφαλος meaning brain, and γράφειν, meaning writing. It may be translated into the phrase "an electrical writing of the brain," or colloquially, "brain wave," or "EEG." Brain waves have assumed more importance in recent years because of the extensive usage of the phenomenon by the U. S. Army Medical Corps and the Veterans Administration hospitals as an additional diagnostic measure in the determination of epilepsy, and in the determination of the location and extent of focal pathology such as brain tumors, brain abscesses, subdural hematomata, and generalized pathology such as encephalitis.

Requirements

The requirements[1] for an electroencephalographic machine may be summarized as follows: The weakest signal that should be detected is of the order of 15 microvolts. (Experimentally, this requirement should extend down to 5 microvolts, and if possible, lower.) The largest signal that normally should be recorded is about 100 microvolts, although, in experimental work, 1 millivolt should be recorded.

To find the order of magnitude of the generator impedance, Thevenin's Theorem may be applied to the brain. If the brain is considered to be a two-terminal network (between pickup electrodes), the magnitude of the electromotive force is generally of the order of 40 to 50 microvolts, and of frequencies between 2 to 40 cycles per second. The impedance in series with the electromotive force is mainly resistive, having a magnitude of between 700 ohms and 15,000 ohms. The lowest frequencies that should be recorded are about 2 cycles, but direct-current recording is undesirable because of the excessive artifact appearing with such a practice.

Artifact may be defined as "any artificial product, any structure or change that is not natural, but is due to manipulation."[2] The meaning of artifact with reference to electroencephalographic work is any tracing irregularity that appears which is not the exact reproduction of the electrical activity of the cerebral cortex.

The highest frequency for brain-wave work is about 35 cycles, but for action-potential and muscle-recording work, frequency response up to 70 cycles is sometimes desired.

Recorder impedance, at the low frequencies recorded, is mainly resistive, having a value of 3000 ohms. The deflection factor of the recorder is about 30 volts per inch.

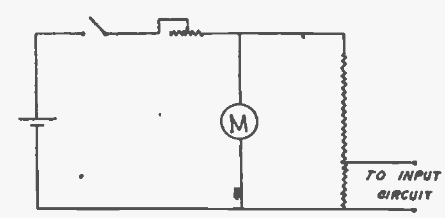

Fig. 1.—Suggested calibration circuit.

A calibrating circuit should be employed which indicates the reference value of the calibrating voltage, such as suggested by Fig. 1. This arrangement permits compensation for variations in calibration-battery voltage.

Microphonic voltage in the output should be less than the output from a 1-microvolt signal at the input.

The power-supply noise should be less than 1 per cent, although the power supply is not the primary source of noise.[3,4] Resistor noise, shot effect, and flicker effect in the first stage of amplification are the greatest sources of noise.

The input circuit should be such as to pass frequencies as low as 1 cycle and up to 70 cycles. Capacitive input is usually used, as shown in Fig. 2. A selector system must be provided in the input in order that a choice of

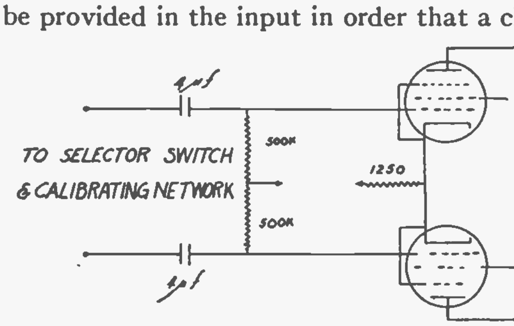

Fig. 2—Typical input circuit for bipolar recording.

* Decimal classification: 621.375.628. Original manuscript received by the Institute, December 10, 1945; revised manuscript received, May 6, 1946.

† Richmond Hill, New York; formerly, electroencephalographic technician at Walter Reed General Hospital, Washington, D. C.

[1] L. W. Max, L. Wiesner, and J. G. M. Bullowa, "Criteria for selection of EEG," *Jour. of Laboratory and Clinical Medicine*, vol. 283, pp. 1868–1871; December, 1943.

[2] W. A. Dorland, "The American Illustrated Medical Dictionary," W. B. Saunders Company, Philadelphia and London, 1944; twentieth edition, p. 147.

[3] C. J. Christensen, G. L. Pearson, "Spontaneous resistance fluctuations in carbon microphones and other granular resistances," *Bell Sys. Tech. Jour.*, vol. 15, p. 181; April, 1936.

[4] F. E. Terman, "Radio Engineers Handbook," McGraw-Hill Book Company, Inc., New York, N. Y., 1943; first edition, p. 292.

from 1 of 16 circuits, with respect to ground, may be made.

Control of low and high cutoff frequencies is desirable in experimental work, but for routine work it is unnecessary. The amount of distortion with any signal should be less than 5 per cent, and preferably under 3 per cent.

The selector system has the requirement of ease of selection of pickup electrodes, and a short-circui ing system is suggested in order to decrease amplifier transient time. The transient time is the time necessary before the amplifier reaches stability after a switch from one electrode to another is made by the technician.

During the war, portability of the equipment was a desirable feature which was not very well fulfilled by the army equipment. One electroencephalographic machine was installed in a 5-ton van truck in the European Theater of Operations, in order that EEG service could be brought to combat echelons of the Medical Corps in that theater. It would have been an aid to portability if the equipment had not been so bulky, and had been of more rugged construction. In addition, if it had had some power supply other than storage batteries, 45-volt B batteries, or 110-volt supply such as a gasoline-driven generator or motor-generator, portability and ease of operation would have improved greatly.

Electrical Equipment

The equipment employed by the army is a commercial amplifier using four independent channels, each channel having five stages of push-pull amplification (see Fig. 3). The circuits are conventional push-pull using low-microphonic tubes in the first stage of amplification and operated at low plate voltage to keep tube noise low. Wire-wound resistors are used in the first stage of amplification. The only outstanding difference from a

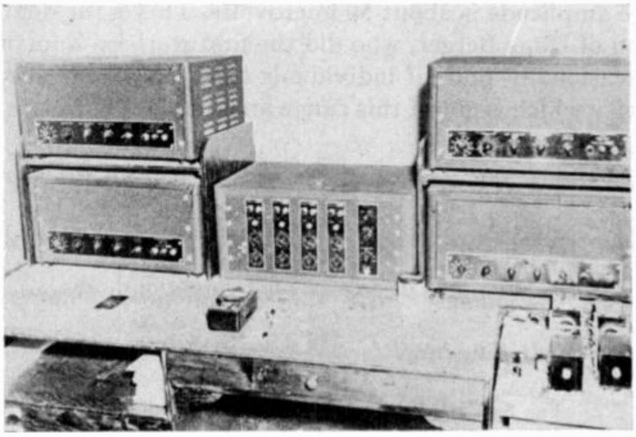

Fig. 3—Electroencephalographic amplifying equipment layout.

conventional audio amplifier, except for battery operation of the first two stages of push-pull amplification, is the value of capacitor used for coupling. The coupling capacitors used are 4 microfarads in value. A choice of three coupling capacitors is available in the fourth stage of amplification, in order to permit variation of the low-frequency-response characteristic of the amplifiers. The high-frequency response of the amplifiers can be varied by a choice of by-pass capacitors across the output of the fourth stage of amplification. The last three stages of amplification are power-line operated. The recording oscillographs (see Fig. 4) are pen-ink types, recording

Fig. 4—Technician running an electroencephalographic record.

on a strip of paper four inches wide which moves at a rate of three centimeters per second in standard recording procedure. Damping of the pens is part electrical and part frictional, with the frictional damping adjustable. The frictional damping is applicable only for a single amplitude of deflection. A two-millimeter arc error is present on full pen deflection, because of the small ink-writer pen radius.

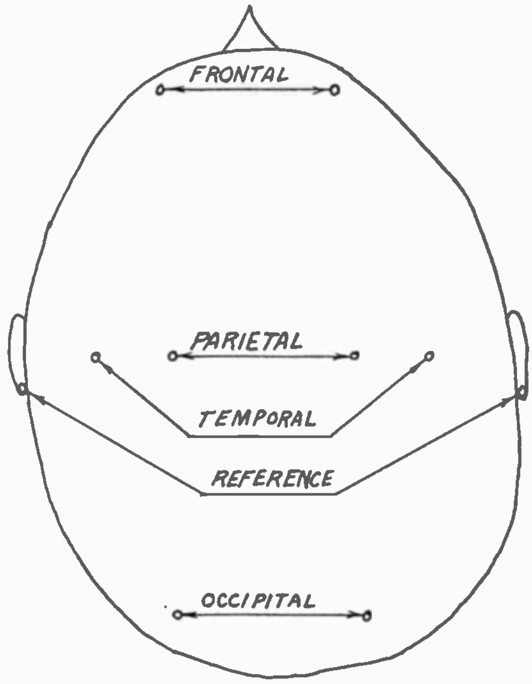

Fig. 5—Electrode placement.

Medical Use and Interpretation

A standard procedure is employed in the army for the placement of electrodes. Where no focal pathology is involved, eight electrodes are placed on the scalp in four symmetrical areas of the hemispheres of the brain: frontal, parietal, occipital, and temporal (see Fig. 5).

It is well known[5] that the electrical activity of a point on the left side of the normal brain is simultaneous with that of a corresponding point on the right side, with respect to frequency, amplitude, and phase. In measurement of the electrical activity of a point on the brain, a reference point must of necessity be used. Its principal criterion for choice is freedom from electrical activity. The ear lobes are the usual points of choice.

In practice, the patient is placed within an electrostatic shield (see Fig. 6) which is grounded at one point. The patient may be sitting up or recumbent, in accordance with practice at the hospital. The patient is normally grounded by means of the ear-lobe electrodes, and

Fig. 6—Patient in position in electrostatistically shielded room.

push-pull (or monopolar) input is taken from ground to the scalp electrodes. If electrical interference, such as from elevators, motors, or other electrical equipment, is picked up, the technique is changed to the extent that the patient is left ungrounded and monopolar input is taken from the ears to the scalp electrodes.

In localization work (see Fig. 7), inputs are taken between electrodes on the scalp, without the use of the ears as reference points. The patient normally remains grounded unless electrical interference should dictate otherwise. This is termed bipolar recording.

For instance, in Fig. 7, area 5 (left occipital) may be considered as a source of electrical activity, assumedly due to some type of pathology. In the course of running a localization record, the electrode choice with the inputs being taken between leads 3 and 5, 5 and 7, and 7 and 3, would arise in normal procedure. This abovementioned recording choice would make use of only three channels of a four-channel amplifier. The fourth channel is left unused.

Since electrodes 7 and 3 are most distant from the electrical activity, negligible activity occurs in this tracing. The tracing of area 5 with reference to area 3 will show the abnormal activity, and area 7 with reference to area 5 will show a similar abnormal activity; but considering the reference points, the activity will show up as a 180-degree phase shift or "phase reversal" in the tracings where the lead to the abnormal electrical activity is common.

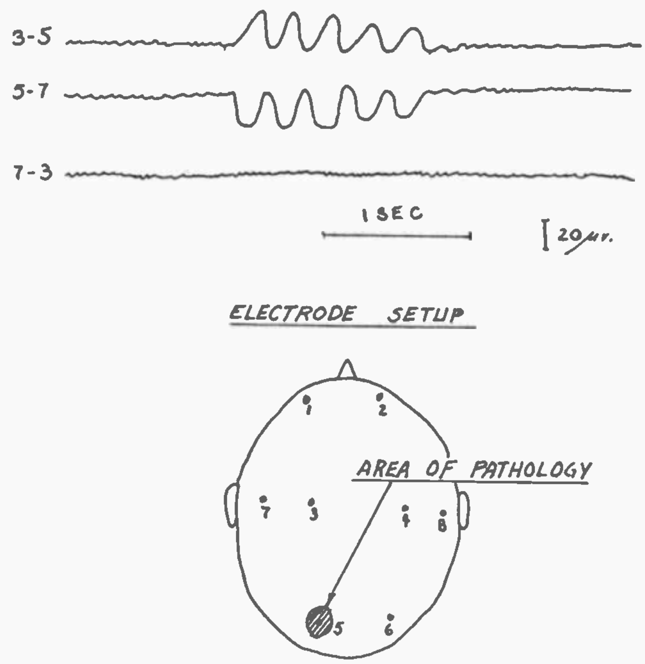

Fig. 7—Phase reversal.

Normal individuals have a dominant rhythm of 8½ to 12 cycles per second with their eyes closed and a mental condition of complete relaxation (see Fig. 8). The average amplitude is about 50 microvolts. This is the definition of Hans Berger, who did the first work on humans. Occasionally normal individuals have an electrical activity which is out of this range and which is both low in

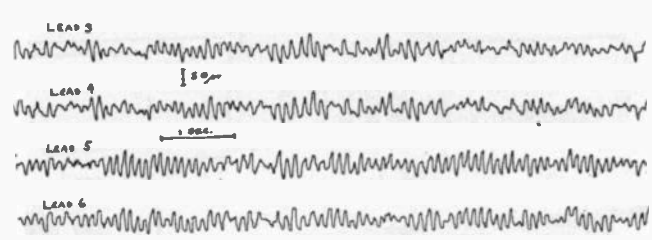

Fig. 8—Sample record from a normal individual.

voltage and fast, and this also is considered normal. Any deviations from these rhythms are considered abnormal. The amount of variation from these frequencies is significant (see Fig. 9). Epilepsy has characteristic wave forms.[6] The grand-mal type consists of waves of 12 to 35

[5] F. A. Gibbs and E. L. Gibbs, "Atlas of Electroencephalography," Lew A. Cummings Company, Cambridge, Mass., 1941.

[6] E. L. Gibbs, F. A. Gibbs, and W. G. Lennox, "EEG classification of epileptic patients and control subjects," *Archives of Neurology and Psychiatry*, vol. 50, pp. 111–128; August, 1943.

per second of increasing amplitude to above 50 microvolts, this burst lasting more than one second, and also 12 to 35 per second having an amplitude below 50 microvolts, this burst lasting longer than three seconds. Either of these bursts must occur in a record previously free

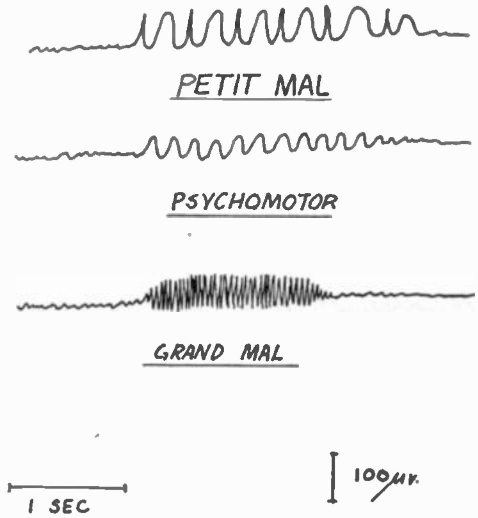

Fig. 9—Characteristic waves.

from such activity. The psychomotor type consists of high-voltage 6-per-second waves or irregular positive spikes in a record previously without such activity. (Contrary to engineering practice, positive is taken as downward, negative upward.) The petit-mal type is a 3-per-second alternating wave-and-spike pattern.

Electrode Problems

Much investigation has been done on electrodes.[5,7–14] Berger's original electrodes were silver wires inserted into the anesthetized scalp. More recently the practice was to use electrodes which were solder discs attached to the end of a fine piece of copper wire, such as No. 28 double-cotton-covered, with a tip jack soldered to the other end. The electrodes were attached to the scalp with collodion around the edge of the electrodes. The scalp area was first cleaned with acetone and then a thin layer of some form of commercial electrode paste was placed on the area. The electrode was then fastened with collodion around the edge of the electrode. This method has the disadvantage that the wires break off the electrodes very often, and the electrodes last less than a week without repairs when many patients are examined. A variation of this system, used at Mason General Hospital, consisted of fastening the frontal and ear-lobe electrodes by means of adhesive tape. The adhesive tape is not as positive a holder as the collodion, and generally produces loose-electrode artifact (see Figs. 10 and 11) which interferes with record interpretation. In warm weather loose-electrode artifact is especially present, because of perspiration on the part of the patient (see Fig. 12).

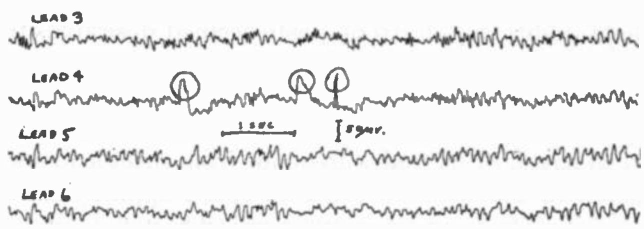

Fig. 10—Loose-electrode artifact shown in lead 4.

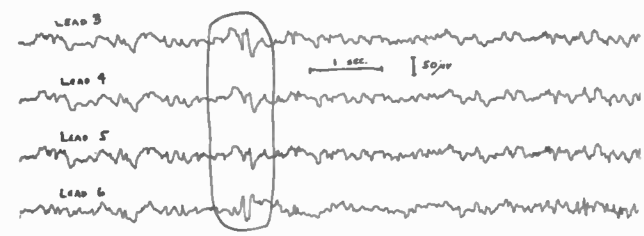

Fig. 11—Loose-electrode artifact common to all leads due to loose ear electrode.

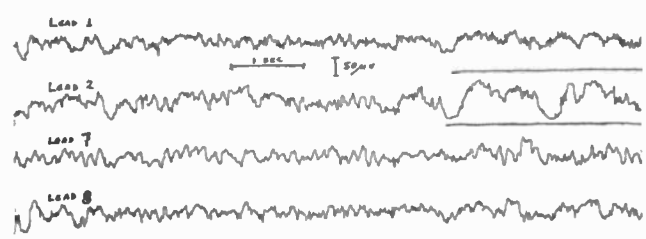

Fig. 12—Perspiration causing artifact in lead 2.

Still another variation used at N. D. Baker General Hospital consisted of the old type of solder-disc electrodes attached to No. 32 enameled wire. These were fastened to the scalp by means of a rather viscous electrode paste. Notwithstanding the ease of application, these electrodes were subject to frequent breakage (i.e., the solder discs had to be replaced), and also these electrodes caused artifact resulting from the slightest movement. Another type of electrode used is a bare copper wire, without a solder tip, with the copper wire bent around so as to touch the scalp, and having ½ inch of the wire fastened with collodion. Because of electrode movement, high contact resistance, and drying of the electrode paste, this system is prone to produce artifact of the loose-electrode type. Headbands are used also, but because of the variation in head types, excessive adjustment time with varying electrode setups, and the electrode artifact of the movement type occurring with the

[7] H. L. Andrews, "New electrode for recording bio-electric potentials," *American Heart Jour.*, vol. 17, pp. 599–601; May, 1939.

[8] A. Baudouin, H. Fischgold, and J. Lerique, "New liquid electrode; application to study of human electrophysiology," *Compt. Rend. Soc. de Biol.*, vol. 127, pp. 1221–1222; 1938.

[9] C. W. Darrow, "Convenient EEG electrode," *Proc. Soc. Exp. Biol. and Med.*, vol. 45, pp. 301–302; October, 1940.

[10] H. H. Jasper and H. L. Andrews, "Human brain rhythms: I. recording techniques and preliminary results," *Jour. Gen. Psychol.*, vol. 14, pp. 98–126; January, 1936.

[11] W. G. Walter, "Location of cerebral tumors by electroencephalography," *Lancet*, vol. 2, pp. 305–308; August 8, 1936.

[12] G. H. Ulett and F. B. Claussen, "Spring pressure contact electrode for use in EEG recording," *Science*, vol. 99, pp. 85–86; January 28, 1944.

[13] H. V. Rice, "A suction type electrode for EEG," *Canad. Jour. Research*, Sect. E., vol. 23, pp. 19–21; April, 1945.

[14] R. Cohn, "A new device for the application of scalp electrodes in EEG," *Jour. Laboratory and Clinical Medicine*, vol. 27, pp. 1344–1345; July, 1942.

headbands, they are not in general use. Occasionally needle scalp electrodes are used. Such an electrode consists of ½ inch of hypodermic needle with a wire soldered to it. In addition to annoying the patient during insertion and becoming detached very easily, needle scalp electrodes also cause artifact of the electrode-movement type due to the oozing of the skin secretions around them.

It appeared at Walter Reed General Hospital that the most desirable electrode would be one which had a larger flexible wire, such as 13-strand, untinned, cotton-loom-covered copper wire. In addition, a cup in the electrode to hold additional electrode paste seemed desirable. In order to support the added electrode weight, a piece of gauze is placed over the electrode before the collodion is applied. A paste is used which is less fluid than commercial paste.[15] Electrodes are made from sheet lead and soldered to the wire. In order to speed application, a stream of air from an air compressor is directed upon the drying collodion. A skilled technician can apply the conventional 8-electrode setup in twenty minutes. This type of electrode overcomes all of the previous undesirable electrode effects. The electrode resistances with this type of electrode (skin resistance permitting) may be kept as low as 500 ohms. In general, high electrode resistance (about 100,000 ohms) means that the electrodes are poorly applied, and slightly less voltage will appear at the input of the amplifiers.

Excessively long testing of electrode resistance with a volt-ohmmeter causes polarization of the electrodes, and adds to the amplifier transient time. The polarization also occasionally produces an electrode artifact, manifested by a swaying of the base line of the recorders.

Perspiration produces a base-line sway due to the dilution of the electrode paste (see Fig. 12). Therefore it is desirable to air-condition the shielded room in which the patient is placed, to minimize artifact. Care should be taken to keep air currents in the shielded room at a minimum, since any swaying of the electrode wires produce artifact.

In addition to artifact from electrodes, electrical activity from muscle (voluntary or involuntary innervation), which has a frequency of from 50 to 70 cycles per second, must be guarded against by having the patient completely relaxed. Occasionally muscle activity produces a "tik" or spike activity, and either of these types of artifact can lead to misinterpretation of the electroencephalographic record.

Artifacts appearing in frontal, parietal, and temporal electrodes occasionally results from eyeball movements, due to the corneal-retinal potential.

Another peculiar type of artifact is that caused by electrocardiac activity. It appears as spikes, usually negative, and may be recognized by its regularity, the spikes occurring at a frequency of about 70 times a minute when the patient is sitting up.

Yet another type of artifact is illustrated in Fig. 13. This occurred with a nearly discharged storage battery. Fluctuations of terminal voltage caused the swaying-base-line artifact. This storage battery, used for heater voltage in the first two stages of push-pull amplification, caused this exceptional base-line movement because it was old. Channel 4 was used as a control.

The interpretation of the resulting electrical activity of the brain is limited to gross distinctions of the waves appearing. Very fine distinctions cannot be made, especially at high amplification. Electrical interference

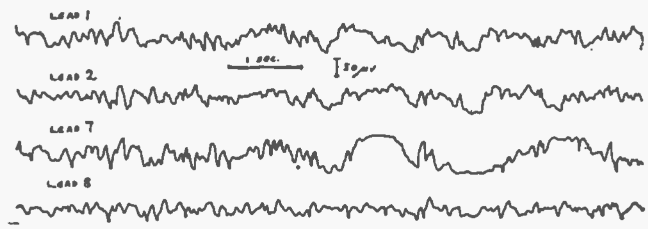

Fig. 13—Artifact caused by a faulty storage battery on channels 1, 2, and 3.

from switching-on of equipment and also amplifier tube and battery noise, and occasionally grounding of the moving element of the recorder due to overdriving, cause obscuring artifacts manifesting themselves as spikes.

Calibration of the amplifier is imperfect. The calibration voltage is obtained from a voltage divider across a dry cell. The voltage of the dry cell may vary from 1.6 volts to 1.3 volts, the latter value causing an 18 per cent error in calibration. There is no zero adjustment to compensate for any variation in dry-cell voltage. The only way to do this at present is to change the dry-cell.

Conclusion

The recording of the electrical activity of the brain is carried out by the use of five-stage push-pull amplifiers, normally consisting of four independent amplifying channels. Recording is monopolar for general work and bipolar for localization work. Electrodes are placed symmetrically in the frontal, parietal, temporal, and occipital areas. The criteria for good electrodes may be summed up as follows: (1) low electrode contact resistance; (2) freedom from artifact; (3) ease of application; and (4) length of service without replacement.

Electrodes are of primary importance in the production of a good record; therefore, painstaking application is of utmost importance. Artifact must be indicated on the record by the technician in order to eliminate the possibility of misinterpretation by the physician.

In addition, a voltmeter across the voltage divider with a meter-zero adjustment would increase calibration accuracy. Pen damping should be some sort of dash-pot arrangement with provision for elimination of arc error.

[15] W. J. Turner and C. S. Roberts, "An adhesive, nondrying electrode paste," *Jour. Laboratory and Clinical Medicine*, vol. 29, p. 81; January, 1944.

Functional Schematic Diagrams*

STUART H. LARICK†, MEMBER, I.R.E.

Summary—**A carefully planned schematic diagram will simplify the study and servicing of electronic equipment. Whereas a conventional schematic merely shows the electrical components and how they are connected, a functional schematic will place these parts on the drawing in such a way as to delineate the circuits they build. This circuit concept versus component concept is the main thesis of this paper. It is expanded by considering major equipments as electrical structures built of circuits, and by treating components as having functions to perform in their circuits. These points are illustrated with functional drawings. Ideas and techniques are suggested which can make schematic diagrams more lucid.**

Introduction

A CAREFULLY planned schematic diagram will simplify the study and servicing of radio sets and other electronic equipment. Conventional schematics show the electrical components and how they are connected; they do not emphasize those components as being parts of *circuits*.

For instance, when several components are in one container, such as a two-section electrolytic capacitor, the conventional diagram will show them drawn next to each other. But components located near each other physically are often unrelated electrically, and when this system is used to describe more complicated sets a confusing and cumbersome drawing may result. The conventional schematic, then, often bows to the physical presentation and sacrifices a clear electrical picture.

Actually the *schematic* diagram should maintain continuity of electrical circuits, and a *wiring* diagram should indicate physical layout. If properly done, the wiring diagram will show the component as a unit and the circuit will be subordinated to the parts in it. The schematic diagram, on the other hand, will present the circuit as a unit, and when there is a conflict the component will be subordinated to it.

Such a diagram is a powerful aid in analyzing the equipment, whether the engineer or technician wants to locate trouble in the set or simply to study it. For, to understand how the equipment works, he must know how its circuits work; and to understand that, he must first know what parts constitute a circuit. If he can see clearly the entire circuit at a glance, he will not laboriously have to construct a satisfying mental picture from a confusing drawing.

The diagram can be made even more helpful if the drawing of parts in the circuit suggests the functions they perform. This functional presentation is another departure from the conventional schematic, since a component is not drawn merely because it exists in the set but because it performs a definite function there.

Once we realize that each component should, wherever possible, be shown in the light of the job it does in the circuit, planning a schematic is like building with blocks. Each circuit has a job to do in its stage; each stage performs a function in its section; while each section does its own job in the set. The radio set then has a definite electrical structure.

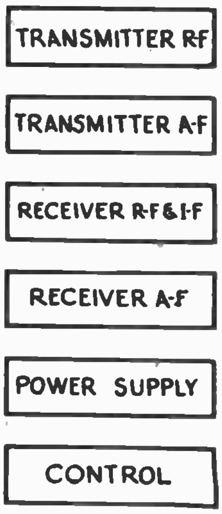

Fig. 1—Over-all layout of the principal sections of an aircraft transmitter-receiver.

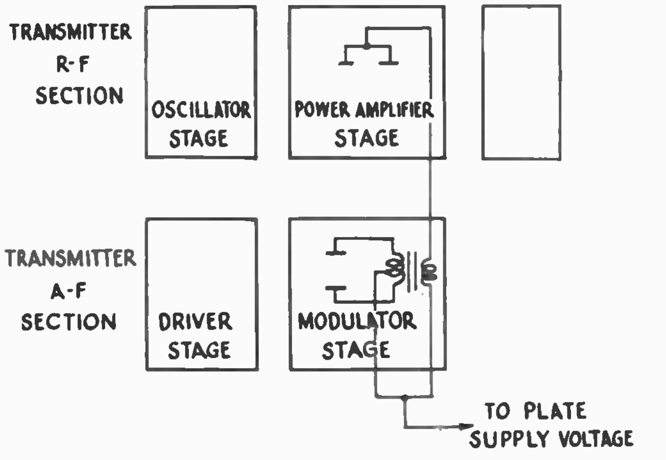

Fig. 2—Sections are broken down into stages. Alignment is maintained where one stage works into another.

Basic Planning

To illustrate, consider an aircraft transmitter-receiver (Bendix RTA) with a built-in power supply and provision for remote-control operation. This set may be considered electrically to be composed of the following sections: transmitter, radio frequency; transmitter, audio frequency; receiver, radio frequency and intermediate frequency; receiver, audio frequency; power supply; and control. A logical arrangement of these sections is shown in Fig. 1. The sections in turn are made up of stages, which are broken down as indicated in Fig. 2.

Each stage of a section, taken as a unit in itself, is

* Decimal classification: R730. Original manuscript received by the Institute, December 28, 1944; revised manuscript received, May 6, 1946; second revision received, June 19, 1946.
† The Larick Manufacturing Company, New York, N. Y.

usually centered about a vacuum tube or a group of tubes such as a push-pull or a parallel stage. The tube circuits (grid, cathode, plate, and possibly screen) then become the units of which the stage is composed. These units are blocked out on the drawing board. For example, the layout of the oscillator unit in the transmitter radio-frequency stage is given in Fig. 3.

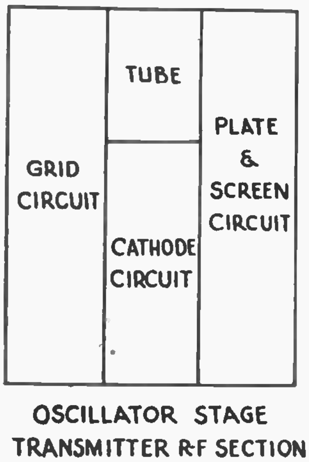

Fig. 3—The circuits which make up a stage are laid out in this general pattern.

Each stage follows the same general pattern, with its circuit blocks as nearly the same in size, shape, and position to that of the oscillator as possible.

Uniform Arrangement

With the spaces organized for the general structure of the sections, the stages, and the circuits, the components that make up the circuits are next laid out to complete the system to the smallest element. A consistent pattern is followed even in the arrangement of parts.

The alternating-current voltage-developing components are drawn at higher levels than the direct-current developing components, as Fig. 4(a) shows. Fig. 4(b) illustrates a complete grid layout for the RTA receiver radio-frequency and intermediate-frequency sections. Observe that components which do similar jobs are drawn on the same level. Thus, for instance, if the technician using the diagram identifies the tuned circuit in one stage, it is easy to locate it in any other stage because his eye travels in short, horizontal lines. The habit developed in the first stage to understand this element is simply repeated in the examination of the other stages. This technique has a sound psychological basis.

There are other techniques which may be employed. Fig. 5(a) shows the coil in direct line with the plate lead and the capacitor tacked to its side. Tracing through the circuit, the eye travels down the plate lead to the tuned circuit and tends to continue in the same straight line in which it is moving. The eye notes the coil first, and has to be diverted to see the capacitor. Hence, the coil occupies a more prominent place on the drawing than the capacitor. Fig. 5(b) shows the capacitor in the more prominent position. Electrically, however, the coil and capacitor work together to perform a function common to both. In fact, they make up another small unit—the tank—and it is the tank which develops the plate voltage. Therefore, this unit should be drawn straight in line with the plate lead, as in Fig. 5(c).

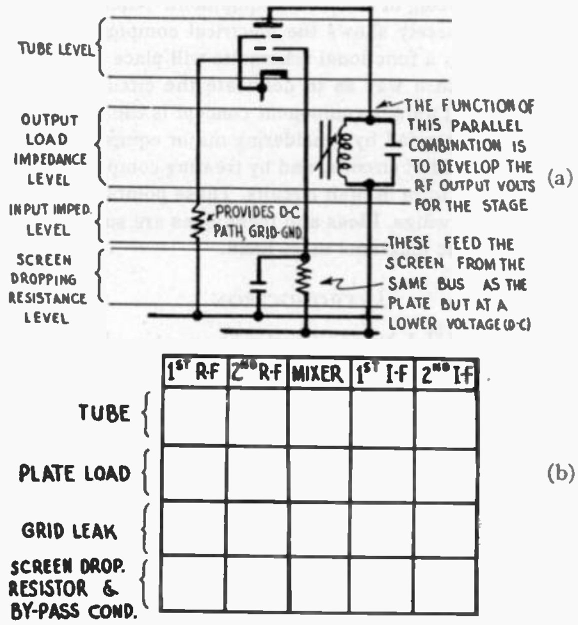

Fig. 4—(a) The components that comprise the circuits are also arranged in a consistent manner. (b) Complete grid layout for RTA receiver radio-frequency and intermediate-frequency sections.

Compare this parallel combination with the commonly encountered cathode-bias resistor and capacitor. The bias resistor develops a direct-current voltage between cathode and ground. The capacitor helps the resistor to do its job more effectively by keeping the alternating-current components of the cathode current

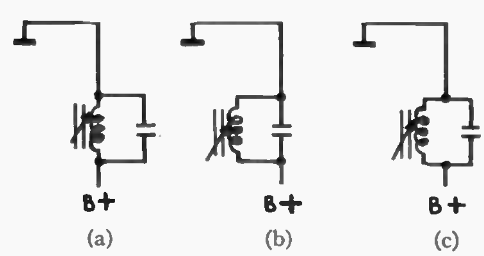

Fig. 5—Comparison in presentations of tank circuit. (a) Coil given undue prominence. (b) Capacitor given undue prominence. (c) Coil and capacitor correctly shown as an electrical unit.

from flowing in the resistor. Electrically, then, the resistance is the main element of the combination, while the capacitance is the supporting element. Hence, the combination is drawn to express this relationship, and again we use one of the artist's tools to direct the eye where we wish (see Fig. 6).

These few examples show some of the subtle devices which serve to make a schematic diagram lucid. The most forceful method, however, is to keep the circuit completely within a small area. This method is best illustrated by the control circuits, which, in a conventional diagram, are apt to ramble all over the drawing.

Clarifying Functions

The typical control-circuit elements—relays, switches, motors, pilot lights; primaries of dynamotors—are all direct-current components and are energized by the aircraft battery. Each circuit starts at the plus terminal of the battery and may be considered to end at the minus (ground) side of the battery.

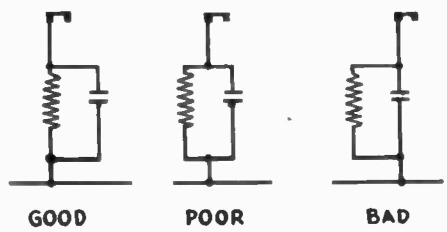

Fig. 6—In the cathode-bias circuit, the resistor is the main element and the capacitor a supporting element. The resistor is therefore given prominence.

The RTA has several such circuits, all connected across the battery; therefore, they are in parallel. To represent these parallel circuits on paper, two bus lines are drawn. Every complete control circuit will lie between the two horizontal lines; thus, a person can tell at a glance exactly what circuit the controls are in and what happens when a switch is closed. The RTA control circuits follow the plan outlined in Fig. 7.

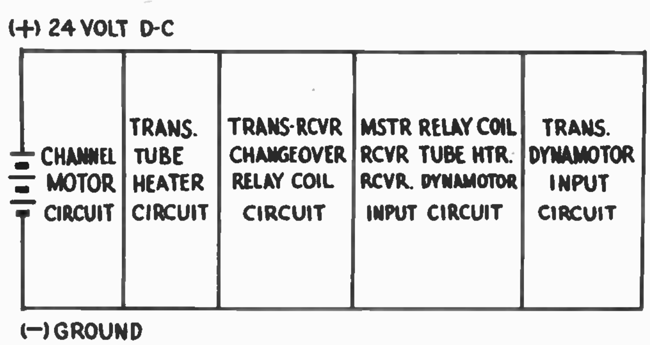

Fig. 7—Typical control circuits are wired in parallel across a battery. Two horizontal bus lines are drawn, and the individual circuits lie between these lines.

In general, relay solenoids are in the control section, while the contacts they control are scattered throughout the set. At first glance, this arrangement looks like a serious drawback. It is turned to advantage, however, by making a separate drawing of the complete relay, and by including a word description of what it does and how it works. Figs. 8 and 9 show how relay K-101 of the RTA is drawn.

In remote-control equipment, the typical control-circuit section is probably the most valuable part of the functional diagram, because these circuits are the most difficult to describe by the more conventional means.

Strangely enough, the most obvious device for obtaining a clearer picture is usually overlooked—that of imparting as much information as possible in words and numbers. Some extremely helpful data are: (1) what each section is; (2) what each stage does; (3) typical voltages that may be measured at the tube sockets; (4) impedance values; (5) where long leads (when they must be used) come from and what they do; (6) labels of switch and relay positions. Drawing extra detail sketches, such as the relay details, often will make the schematic more understandable.

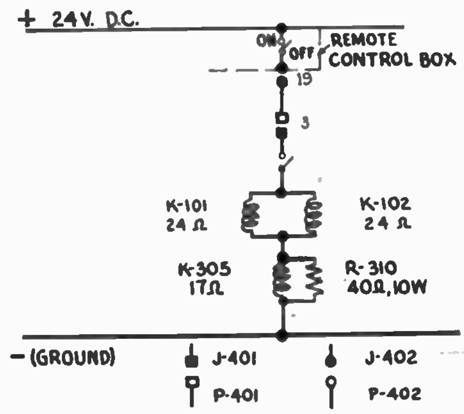

Fig. 8—Transmitter-receiver change-over relay coil circuit.

It is recognized that, in trying to draw consistent functional diagrams, there may be conflicts. However, this is a condition inherent in any design situation, and may be solved in the usual way—that is, by compromise. This is especially true of the more recent circuits. For instance, a component may have more than

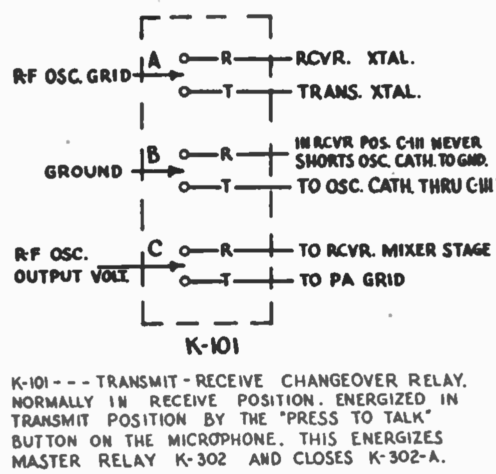

Fig. 9—A separate drawing is made of a complete relay. Above is relay K-101 of the RTA.

one function in a circuit, or it may act in several circuits. In such a case, it may not be possible to carry out the functional idea completely. It may only be possible to show one of the functions of that particular component.

This paper is not intended to lay down hard-and-fast rules of how to draw schematics, but rather to stimulate more thought about drawing them. Just as careful thought and planning are essential to a good chassis layout, so are they important to a good schematic diagram.[1]

[1] Stuart H. Larick, "Taming the schematic diagram," *Bendix Radio Engineer*, vol. 1, pp. 19–23; October, 1944.

Contributors to Waves and Electrons Section

CLEDO BRUNETTI

Cledo Brunetti (A'37–SM'46) was born on April 1, 1910, at Virginia, Minnesota. He was graduated at the head of his class in electrical engineering at the University of Minnesota in 1932. Continuing with graduate work and as a teaching fellow and instructor, he obtained the first Ph.D. degree in electrical engineering granted at the University. From 1937 to 1941 he was on the faculty of Lehigh University as assistant professor of electrical engineering. In 1941–1942 he lectured on radio at George Washington University, evening classes. During the summers of 1939 and 1940 he was research associate in the radio section of the National Bureau of Standards. In May, 1941, he left Lehigh to work at the Bureau on the development of the radio proximity fuze. Later he became alternate chief of the electronics development section. In 1943 he organized and headed the production engineering section of the Ordnance Development Division. At present, he is chief of the pilot engineering section.

In 1941, Dr. Brunetti was recognized by Eta Kappa Nu as America's outstanding young electrical engineer. He is a member of Sigma Xi, Tau Beta Pi, and Eta Kappa Nu.

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WALTER G. EGAN

Sidney Frankel (A'37–SM'44) was born on October 6, 1910, in New York City. Rensselaer Polytechnic Institute conferred three degrees on him: the B.A. degree in electrical engineering in 1931, the M.A. degree in mathematics in 1934, and the Ph.D. degree in 1936. He was an instructor in mathematics from 1931 to 1933.

Dr. Frankel served as a sound-recording engineer with the Brooklyn Vitaphone Corporation from 1936 to 1937. In 1937 and 1938, he was an assistant engineer in the design and development of electronic flight instruments for the Eclipse Aviation Corporation.

He joined the Federal Telegraph Company staff at Newark, New Jersey, in 1938 as an engineer on the design and development of radio transmitters. In 1943, he was transferred to the Federal Telephone and Radio Laboratories, now the Federal Telecommunication Laboratories. At present he is engaged in the development of components for microwave systems. Dr. Frankel is a member of Sigma Xi.

SIDNEY FRANKEL

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Walter G. Egan (S'42–A'45) was born at New York City on October 12, 1923. He studied electrical engineering at the College of the City of New York from 1941 until 1943, when he was called to active military duty from enlisted reserve corps status. He worked for the Bruce Engineering Company of New York at drafting in the summer of 1942. Just prior to entering the service, he worked part time for Dr. A. K. Apisdorf, of New York, as an electroencephalographic technician and in the design of electroencephalographic equipment.

Mr. Egan served in the Signal Corps as a central-office wire chief until December, 1944, at which time he was transferred to the medical corps to serve as an electroencephalographic technician. His assignments in this capacity were at Walter Reed, Wakeman, Beaumont, and Brooke general hospitals. He is a radio amateur and a member of the American Radio Relay League. He is at present resuming studies at college.

JOHN J. GLAUBER

John J. Glauber (A'27–SM'45) was born in New York City, July 31, 1903, and received the M.E. degree from Stevens Institute of Technology in 1925. From 1925 to 1927, he was associated with the U. S. Tool Company, Ampere, N. J., engaged in variable-condenser design. In 1927, he joined the Arcturus Radio Tube Company, Newark, N. J., as laboratory assistant, and was chief engineer from 1933 to 1936. He then joined the Westinghouse Lamp Company, Bloomfield, N. J., as a vacuum-tube development engineer, and in 1939 became development engineer for the National Union Radio Corporation, Newark, N. J.

Since 1941, Mr. Glauber has been associated with the vacuum-tube department of the Federal Telecommunications Laboratories, New York City.

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W. S. Hinman, Jr. (SM'46), received the B.S. degree in electrical engineering from the Virginia Military Institute in 1926. He took the Westinghouse Student Engineering Course in 1926–1927 and was employed as radio engineer in the Westinghouse Plant at Springfield, Mass., during 1927–1928.

Mr. Hinman joined the staff of the National Bureau of Standards in 1928. As a

W. S. HINMAN, JR.

member of the radio section, he assisted in the development of radio aids to air navigation for the Department of Commerce. This work included development of the present radio-range beacon system, of the glide-beam landing system, and of airplane ignition shielding, as well as some of the early work on aircraft radio compasses.

From 1936 to 1939, he was engaged in the development of a radiosonde system for automatically transmitting and recording atmospheric conditions of the upper air through the use of small free balloons. He is coinventor of the system in current use, particularly during the war. He is also coinventor of a parallel system, an automatic weather station operated as a robot in remote locations.

Mr. Hinman started work on the radio proximity fuze in late 1940. Through the war period he headed the engineering staff responsible for the development, design, and production of bomb, rocket, and mortar radio fuzes, and is now chief engineer of the ordnance development division of the National Bureau of Standards.

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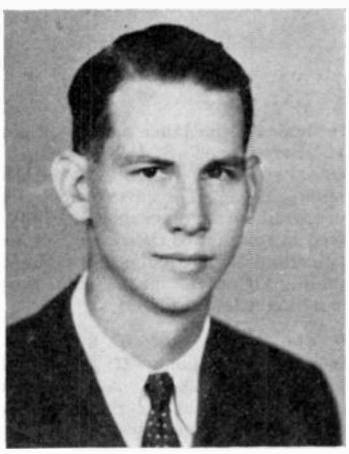

Robert B. Jacques

Robert B. Jacques, (M'45) was born at Akron, Ohio, on December 22, 1911. He received the B.E.E. degree in electrical engineering from the Ohio State University in 1942. He was engaged at Ohio State University in research work on antennas and reflection cross-section measurements by means of radar from 1942 until 1944. He then undertook a project to measure the space-wave radiation patterns of a number of Signal Corps antennas using techniques developed at Ohio State University.

In February, 1946, Mr. Jacques joined The Institute of Radio Engineers' headquarters staff in the capacity of technical secretary. In September, 1946, he returned to the Ohio State University, where he is now engaged in research in the field of television. He is a member of the American Physical Society, and also a member of Tau Beta Pi and Eta Kappa Nu.

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For a biographical sketch and photograph of George H. Brown, see the February, 1946, issue of the Proceedings of the I.R.E. and Waves and Electrons.

Stuart H. Larick (S'41–A'43–M'45) was born on September 7, 1918, in New York City. He studied liberal arts and social sciences at the College of The City of New York, then transferred to the School of Technology at the same college, and received the B.E.E. degree in 1941. While at school he was engaged part time by the Municipal Broadcasting System. In 1941 he was employed by the Electric Boat Company in Bayonne, N. J. In July of the same year he joined the engineering department of Bendix Radio Division, Baltimore, Maryland. Since October, 1945, he has been associated with the Larick Manufacturing Company in New York City.

Stuart H. Larick

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Wendell C. Morrison (S'40-A'41) was born on September 13, 1915, at Sioux City, Iowa. He received the A.B. degree in 1937 from Morningside College, and the B.S. degree in 1939 and the M.S. degree in 1940, from the University of Iowa.

Wendell C. Morrison

Mr. Morrison was employed by the RCA Manufacturing Company at Camden, New Jersey, from 1940 to 1942. In 1942 he transferred to the RCA Laboratories at Princeton, New Jersey, where he is employed at present in the antenna research section. Mr. Morrison is a member of Sigma Xi, Tau Beta Pi, and Eta Kappa Nu.

Joel P. Wallenstein

Joel P. Wallenstein (S'42–A'44) was born on October 11, 1922, in Elizabeth, New Jersey. He received the B.S. degree in electrical engineering from the Newark College of Engineering in 1942. In 1942, he joined the Federal Telephone and Radio Corporation, Newark, New Jersey, as a vacuum-tube engineer engaged in the development of high-power tubes. Since September, 1946, he has been engaged in the engineering consulting field.

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D. S. Wicks

Abstracts and References

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ACOUSTICS AND AUDIO FREQUENCIES

534.1 **3157**
Approximate Methods for the Study of Sound Sources—P. G. Bordoni. (*Alta Frequenza*, vol. 14, pp. 225–226; September–December, 1945.) Abstract of a paper in *Acta. Pont. Acad. Sci.* (Vatican City) vol. 8, pp. 61–66; 1944.)

534.121.1 **3158**
The Fundamental Frequency of Vibration of Rectangular Wood and Plywood Plates—R. F. S. Hearmon. (*Proc. Phys. Soc.*, vol. 58, p. 487; July 1, 1946.) Discussion of 1145 of May.

534.13 **3159**
Radiation Characteristics of a Rigid Sphere Having an Oscillating Shell—P. G. Bordoni. (*Alta Frequenza*, vol. 14, pp. 226–227; September–December 1945.) Abstract of a paper from *Commentationes Pont. Acad. Sci.* (Vatican City), vol. 8, pp. 505–525; 1944. The shell subtends an angle of $\pi/2$ at the center. Analysis shows that the device can (a) radiate an acoustic power that remains almost constant with changing frequency provided the radius of the sphere is less than a third of the wavelength; for higher frequencies the power slowly decreases; (b) produce along its axis an acoustic pressure increasing with frequency until it amounts to twice its initial value.

534.13:621.396.611.1 **3160**
The Equivalent Circuit of a Spherical Vibrator—G. Sacerdote. (*Alta Frequenza*, vol. 15, pp. 28–33; March, 1946.) A theoretical analysis of the specific acoustic impedance of a spherical vibrator of order n. The equivalent circuit consists of a ladder network with series capacitors and shunt inductors (with values in harmonic progression) terminated in a pure resistance.

534.43:621.395.613.32 **3161**
Carbon Phonograph Pickup—A. B. Kaufman and E. N. Kaufman. (*Electronics*, vol. 19, pp. 162–168; September, 1946.) A description of the preliminary design of a pickup based on the carbon-microphone principle.

534.844/.845 **3162**
Absorption and Scattering by Sound-Absorbent Cylinders—R. K. Cook and P. Chrzanowski. (*Jour. Res. Nat. Bur. Stand.*, vol. 36, pp. 393–410; April, 1946.) Expressions are developed for a normally incident wave, the surface of the cylinder having an assumed normal acoustic impedance. The theory predicts, and measurements in a reverberation room confirm, that cylinders may have coefficients greater than unity. Reverberation-room statistics are also developed for spherical absorbers.

534.88 **3163**
Echo Depth Sounder for Shallow Water—G. B. Shaw. (*Electronics*, vol. 19, pp. 88–92; September, 1946.) A review of requirements, with a technical description of the Submarine Signal Company model 788A precision ultrasonic depth recorder suitable for hydrographic surveying. Recording range 75 feet, which can be set to cover any part of a total depth range from 3 feet to 250 feet. Accuracy ±3 inches up to 50 feet, ±6 inches for 50 to 125 feet, and 1 per cent for 125 to 250 feet. Compensating controls are provided for draft, squat, tide, elevation, and sound velocity. Magnetostriction transducers are used at 21.5 kilocycles. The transmitter is excited by an unusual capacitor-discharge system. Circuit diagrams of the driver and receiver are given.

534.88:534.321.9 **3164**
The "Sonicator"—(*Radio Craft*, vol. 17, pp. 752–793; August, 1946.) A horn-type loudspeaker unit at the focus of a parabolic reflector emits sound pulses of 100-microseconds duration once a second. The echoes are received on a crystal microphone near the focus of the reflector, amplified, and used to operate a neon light revolving once a second behind a transparent disk. The position of the flash on the disk gives the distance of the target, the direction is obtained by rotation of the reflector to give the maximum echo. The range is 550 feet down to 5 feet. An invention by L. Gould.

621.395.61 **3165**
Mechanical Impedance and the Classification of Microphones—S. P. G. Bordoni. (*Alta Frequenza*, vol. 14, pp. 218–224; September–December, 1945.) The distinction between pressure, gradient, and velocity microphones is indicated in relation to their mechanical characteristics, and, in particular, the effect of the surrounding air on the mechanical impedance of a diaphragm is considered.

621.395.61 **3166**
Meet the Microphone—H. J. Seitz. (*Radio News*, vol. 36, pp. 28, 74; August, 1946.) A brief review of the characteristics and special uses of modern microphones of the capacitor crystal, and ribbon types.

621.395.625.3 **3167**
Theoretical Response from a Magnetic-Wire Record—M. Camras. (PROC. I.R.E. AND WAVES AND ELECTRONS, vol. 34, pp. 597–602; August, 1946.) "This paper considers the effect of magnetic properties of a record wire on the output level and frequency response of a magnetic recording system. The amount of magnetic energy that can be stored at each wavelength determines the voltage output to be expected from a given translating head. Frequency response for a typical record wire is calculated according to derived relations, and compared with experimental data."

621.395.645.3 **3168**
Cathode Follower for Power Amplifier—Stevens. (*See* 3206.)

621.396.615.029.3 **3169**
Audio Oscillators—J. C. Hoadley. (*Radio News*, vol. 36, pp. 38–40, 98; August, 1946.) Two types of resistance-capacitance or Wien-bridge oscillators are described, one using variable C and the other variable R for controlling the frequency. Circuit diagrams and constructional details are given.

621.396.667 **3170**
Tone Control Circuits—L. A. Wortman. (*Radio Craft*, vol. 17, pp. 763, 781; August, 1946.) Five simple resistance-capacitance circuits are given.

786.6:621.383 3171
Photoelectric Tone Generator—Greenlee. (*See* 3399.)

AERIALS AND TRANSMISSION LINES

621.392 3172
Study of the Diffraction and Reflection of Guided Waves—J. Ortusi. (*Ann. Radioélect.*, vol. 1, pp. 87–133; October, 1945.) A theoretical and experimental study of a plane H_{01} wave in a rectangular guide. The introduction defines the coefficients of reflection and transmission and the characteristic impedances. The analogy between a guide carrying a H_{01} wave and a lightly damped transmission line is indicated.

The thermocouple apparatus used for measuring the field intensity in the guide and the methods of measuring wavelength and the coefficients of reflection at an obstacle in the guide are described.

The impedance and reflection coefficient of a wire across the guide are calculated.

The theoretical treatment of diffraction is based on Kottler's presentation of Huyghens' principle (*Ann. d. Phys.* p. 456; 1923.). The following cases are analyzed: opening in a rectangular guide, sectoral horn, and a cylindrical mirror. Experimental investigation of the diffraction and reflection at the opening of a guide is described, and it is concluded that only for large apertures (a and $b>2\lambda$) are Kottler's formulas of good accuracy.

The effect of a change of dielectric in a guide is analyzed, and its application to the measurement of dielectric constant and damping coefficient is described.

Obstacles in the form of a conducting disk with a small hole, a wire, and a change of curvature of the wave are considered in detail, using the impedance representation in conjunction with reflection and transmission coefficients. Corrections are given in *Ann. Radioélect.*, vol. 1, p. 276; January, 1946.

621.392 3173
The Theory and Experimental Behaviour of Right-Angled Junctions in Rectangular-Section Guides—J. T. Allanson, R. Cooper, and T. G. Cowling. **The Experimental Behavior of the Coaxial Line Stub**—J. Lamb. (*Jour. I.E.E.* (London), vol. 93, pp. 359–360; August, 1946.) Long summary of 2133 and 2134 of August.

621.392 3174
Ideas on Waveguides—Y. Rocard. (*Rev. Tech. Com. Franç. Thomson-Houston*, pp. 5–19; April, 1946.) An elementary survey of the velocity and field relations in a waveguide, and of the various modes of propagation. Reference is made to filters, mode separators, mode converters, detectors, diaphragms, and horns.

621.392 3175
The Relation Between Nodal Positions and Standing Wave Ratio in a Composite Transmission System—E. Feenberg. (*Jour. Appl. Phys.*, vol. 17, pp. 530–532; June, 1946.) "Reflection generally occurs at a lossless transition region joining two uniform lossless lines. If the output line feeds into a matched load (no reflection) a standing wave ratio η_0 different from unity exists on the input side of the transition region. If the output line is terminated by a movable short circuit, a relation exists between the nodal positions on opposite sides of the transition section. The relation can be used to determine η_0 thus dispensing with the need for a calibrated detecting system to measure this quantity."

621.392 3176
Transmission Line Phenomena at Audio and Radio Frequencies—H. Clark. (*Trans. S. Afr. I.E.E.*, vol. 37, pp. 149–158; June, 1946, discussion, pp. 158–162.) An introduction to the theory of transmission lines based on the conception that free electrons in a conductor behave as the molecules of a gas, having random velocities when the conductor is isolated, but acquiring an additional drift velocity when a polarizing electromotive force is applied.

621.392: [534+535 3177
Extension of the Characteristic-Impedance Concept to Acoustics, Optics and to the Theory of Vibrating Strings—Bedeau. (*See* 3262.)

621.392:621.317.33.029.64 3178
The Use of the Impedance Concept as Applied to Wave Guides—G. Williams and H. C. Bolton. (*Phil. Mag.*, vol. 36, pp. 862–873; December, 1945.) The analogy between lines and wave guides is used to derive a wave-guide method for the measurement of properties of dielectrics at centimeter wavelengths. Expressions corresponding to the R, G, L, and C of a line system are given for both H and E waves, and the method for dielectric measurement is first illustrated by reference to a coaxial line. Applying the impedance concept leads to an expression for the dielectric constant in terms of the wavelength in air, the cut-off wavelength of the guide, and the wavelength in the dielectric-filled guide. The latter is obtained from probe measurements of the wave pattern in the guide, and gives experimental results in agreement with those given by other methods.

621.392.2+621.396.44]:551.574.7 3179
The Effect of Sleet on the Propagation of Carrier Waves along High-Voltage Transmission Lines—Wertli. (*See* 3416).

621.392.21:621.315.1+621.396.664]:621.396.712 3180
The Design and Use of Radio-Frequency Open-Wire Transmission Lines and Switchgear for Broadcasting Systems—F. C. McLean and F. D. Bolt. (*Jour. I.E.E.* (London), vol. 93, pp. 362–364; August, 1946.) Long summary of 2139 of August.

621.392.5 3181
Simplified Treatment of Some Main Points in the Theory of Quadripole.—Guerbilsky. (*See* 3202.)

621.396.44+621.398]:621.315.052.63 3182
Carrier-Current Communication over High-Voltage Transmission Lines—Hancess. (*See* 3417.)

621.396.67 3183
Radiation Resistance of Loaded Antennas—R. C. Raymond and W. Webb. (*Phys. Rev.*, vol. 70, p. 114; July 1–15, 1946.) Experimental determinations have been made of driving-point impedances for antennas with various forms of metallic and dielectric loading. Resistances at resonance are compared with resistances calculated by the Poynting-vector method for assumed current distributions. For a given distribution the resistance is a function of only the length of the antenna in wavelengths. Measured current distributions fell between the curves for uniform and for sinusoidal distribution. Abstract of an American Physical Society paper.

621.396.67 3184
Determination of the Electric Intensity Near an Aerial Cage—J. C. Simmonds. (*Phil. Mag.*, vol. 36, pp. 758–770; November, 1945.) Two methods are developed which enable the charge distribution and hence the electric intensity and corona voltage of an aerial cage to be determined. In the first, easily calculated up to a 6-wire cage only, the wires are assumed to be of diameter small compared with the distance apart, the charge distribution being evaluated in a determinant form. The other method is applicable when the cage is formed from a large number of wires, the distances apart being small compared with the cage diameter. Measurements on rubber-sheet models checked by the first method to within 5 per cent, and were then used to confirm the second method.

621.396.67 3185
Simple Transmission Formula—G.W.O.H. (*Wireless Eng.*, vol. 23, pp. 235–236; September, 1946.) Discussion of the treatment by Friis (2282 of August) of the ratio of received power to transmitted power in terms of the "effective areas" of the aerials.

621.396.674 3186
Advantages of a Low-Impedance Loop for Broadcast Reception—F. Bedeau. (*Rev. Tech. Comp. Franç. Thomson-Houston*, pp. 59–71; January, 1944.) Comparison of the fields from electric and magnetic radiators of interference shows that a receiving aerial should be of the loop type to give the best signal-to-interference ratio. The reduction of antenna effect by balancing or screening the loop is essential for the best performance, and a single-turn loop, coupled by a suitable transformer to the input circuit of the receiver is the system recommended. The pickup factor (*hauteur d'entrée*) is analyzed for this system, and typical measured values in the bands 150 to 300 kilocycles and 600 to 1500 kilocycles are given. See also 3187 (Vladimir).

621.396.674 3187
Low Impedance Loop Antenna for Broadcast Receivers—L. O. Valdimir. (*Electronics*, vol. 19, pp. 100–103; September, 1946.) Low-impedance loops are easier to make and are less affected by age and humidity than the corresponding high-impedance loops. An account of the design of associated transformers is given, and curves show the conditions for maximum gain.

621.396.677 3188
A Generalized Radiation Formula for Horizontal Rhombic Aerials: Part 2—H. Cafferata. (*Marconi Rev.*, vol. 9, pp. 64–69; April–June, 1946.) Continuation of 1456 of June. The reflection factor of an imperfectly conducting earth and the general radiation formula for a perfect earth are derived, and the general equation for radiation from the array is set out. To be concluded.

621.396.677 3189
Dual-Rocket Antenna Characteristics—G. Hendrickson. (*Radio*, vol. 30, pp. 14–15; July, 1946.) Rocket antennas are described. They are longitudinally slotted cylinders and the potential difference is applied across the slot. The radiation is similar to that from a large number of coaxial loops stacked one above the other. The radiation patterns and power gains are given for single and double rockets and for an array of two double-rocket antennas. For the latter it is 7.5 decibels.

621.396.677 3190
Polar Diagrams: Experiments with a Half-Wavelength Receiving Aerial and a V-type Wire-Netting Reflector—J. S. McPetrie, L. H. Ford, and J. A. Saxton. (*Alta Frequenza*, vol. 14, pp. 119–122; March–June, 1945.) Long summary in Italian of 2612 of 1945.

621.396.677:621.398 3191
A Simple Method of Controlling the Beam Antenna—E. Harris. (*Radio News*, vol. 36, pp. 60, 62; August, 1946.) A Wheatstone-bridge relay-operating circuit for the remote control of a rotating array.

621.315.052.63+621.317.083.7 3192
Télétransmissions par Ondes Porteuses dans les Réseaux de Transport d'Énergie à Haute Tension [Book Review]—A. Chevallier. Dunod, Paris, 111 pp., 124 fig. (*Wireless Engr.*,

vol. 23, p. 259; September, 1946.) Deals with the protection of high-voltage networks by means of superposed high-frequency currents.

CIRCUITS

518.5:621.3 3193
Computation Problems in Circuit Design—Baker. (*See* 3365.)

621.314.2.029.5:621.396.621.54 3194
Two-Frequency I.F. Transformers—Thompson. (*See* 3430).

621.314.6 3195
A Note on Empirical Laws for Non-Linear Circuit Elements and Rectifiers—D. B. Corbyn (*Beama Jour.*, vol. 53, pp. 245–252; July, 1946.) A theoretical treatment leads to the deduction of specific parameters analogous to specific resistance or conductance. It is shown that limitations are imposed on the values which the index n (of the current versus voltage law) may take for either symmetrically or asymmetrically conducting elements such as rectifiers, and that n cannot, in general, be treated as a continuous variable.

621.318.7+537.228.1 3196
Piezo-Electric Crystals and Their Use in Electrical Wave Filters—P. Scherrer and B. Matthias. (*Brown Boveri Rev.*, vol. 31, pp. 316–322; September, 1944.) Crystals of potassium and ammonium phosphate can be used with advantage in lattice band-pass filters for 10 to 100 kilocycles. They can be artificially grown, they are more stable than Rochelle salt and give wider bandwidths than quartz crystals. The piezoelectric effect is explained using a mechanical model, and the insertion-loss characteristic of a filter using potassium phosphate crystals is graphed.

621.392 3197
Balancing System—P. D. Andrews. (*Radio*, vol. 30, p. 16; July, 1946.) A circuit is described for connecting a push-pull source to an unbalanced load. The primary feature is a special capacitor having two ganged variable sections built so that the series value of capacitance remains constant. Summary of U.S. patent 2,380,389.

621.392.091 3198
Simplified Method of Plotting-Attenuation Curves—L. S. Biberman. (*Radio*, vol. 30, pp. 12–13; July, 1946.) Attenuation characteristics of many circuits plot as straight lines and circular arcs on semi-log paper. Illustrations are given.

621.392.4 3199
Link-Coupled Coil Design—S. Sabaroff. (*Communications*, vol. 26, pp. 16–19, 45; August, 1946.) Analysis of a design procedure, assuming resistive loads. A nomogram is given.

621.392.43 3200
New Method of Impedance Matching in Radio-Frequency Circuits—G. Guanella. (*Brown Boveri Rev.*, vol. 31, pp. 327–329; September, 1944.) Description of a transformer method depending on double-winding of coils, which can be used for impedance matching and for coupling symmetrical and unsymmetrical circuits. The matching remains substantially independent of frequency over a relatively wide range of the ultra-high-frequency region.

621.392.43 3201
Electric Filters built up from Choke Coils and Condensers for Frequencies up to 60 kc/s—K. Ehrat. (*Brown Boveri Rev.*, vol. 31, pp. 329–330; September, 1944.) Mentions points to be observed when using powdered-iron cores, and gives attenuation curves for filters to pass 0 to 1000 cycles and 2.8 to 3.2 kilocycles.

621.392.5 3202
Simplified Treatment of Some Main Points in the Theory of Quadripoles—A. Guerbilsky. (*Ann. Radioélect.*, vol. 1, pp. 191–207; January, 1946.) The fundamental theorems of network theory are stated, and it is shown that, in general, three parameters determine any quadripole, while two are sufficient for a symmetrical quadripole.

Symmetrical quadripoles and the implications of Bartlett's theorem are discussed. Particular attention is devoted to the treatment in terms of lattice networks and their properties. An account of the asymmetrical quadripole is given, and its equivalence to a symmetrical quadripole followed by an ideal transformer is demonstrated.

Appendixes deal respectively with transmission lines, the mid-band iterative impedance of a narrow-band band-pass filter, and the approximate calculation of the propagation constant.

621.394/.395].645.3 3203
Radio Design Worksheet No. 50—Note on Analysis of Push-Pull Amplifiers with Negative Feedback—(*Radio*, vol. 30, p. 20; July, 1946.)

621.394/.397].645.22 3204
Transient Response of Tuned-Circuit Cascades—D. G. Tucker. (*Wireless Eng.*, vol. 23, pp. 250–258; September, 1946.) The response of an amplifier with N circuits, each with the same resonant frequency ω_0, to a pulse of carrier frequency ω is evaluated by repeated application of Duhamel's integral. When $\omega=\omega_0$ the envelope of the output pulse is found in terms of a series equivalent to the incomplete gamma functions; when $\omega\neq\omega_0$ only the last (Nth) terms of the series gives the envelope. "A comparison of the responses of tuned-circuit cascades with those of underived band-pass filters shows that for equal component qualities in the two cases, two tuned circuits in cascade are approximately equivalent, for pulse transmission applications, to a single-section band-pass filter using 50 per cent more components."

621.395/.397].645:621.396.619 3205
Carrier-Frequency Amplifiers—C. C. Eaglesfield. (*Wireless Eng.*, vol. 23, pp. 258–259; September, 1946.) An amendment to 1474 of June (Eaglesfield), suggested by van der Pol, concerning the influence of a linear 4-terminal network on a carrier with small amplitude or frequency modulation.

621.395.645.3 3206
Cathode Follower for Power Amplifier—C. Stevens. (*Radio News*, vol. 36, pp. 52–54, 80; August, 1946.) Constructional details of an audio-frequency amplifier with a cathode-follower push-pull output stage.

621.396.24.029.63 3207
Development Work in the Decimetre Wave Field—Schüpbach and De Quervain. (*See* 3361.)

621.396.611 3208
Average Frequency Stability [with Deformation] of Cavity Resonators—K. F. Niessen. (*Physica, 's Grav.* vol. 9, pp. 145–157; February, 1942. In German.) For simplicity only deformations of a tensional form are considered. The axis of symmetry of the applied deformations is always chosen to be along one or other of the three principal axes of the cavity. One or two of these three deformations transform the original fundamental frequency to that of the deformed cavity while the other(s) lead to a higher frequency. The three new resulting frequencies are averaged. The frequency stabilities of the sphere and of the cube are very little different if the deformations satisfy the condition of constant surface area. The above is valid when only the linear terms in the frequency variation are taken into account. See also 3209 and 3210 below (Niessen).

621.396.611 3209
On the Frequency Stability of Certain Cavity Resonators in an Electric Circuit—K. F. Niessen. (*Physica, 's Grav.*, vol. 9, pp. 539–546; June, 1942. In German.) In deriving the frequency stability of cavities it is necessary to consider, in addition to the absolute value of the frequency variation, the average of such values when several deformations are possible. A comparison of the cube and the sphere is in favor of the former (about twice as good) for the case of expansion in one of the three mutually perpendicular dimensions when the other two dimensions contract so as to preserve constant surface area. The same applies for a contraction in one dimension instead of an expansion. On the basis of these calculations it is supposed that, in general, the cube exhibits the least frequency deviation when the two cavities are subjected to small irregular deformations. See also 3208 and 3210 (Niessen).

621.396.611 3210
Practical Remarks on the Frequency Stabilization of Spherical Cavity Resonators—K. F. Niessen. (*Physics, 's Grav.*, vol. 9, pp. 768–772; July, 1942. In German.) In order to reduce the frequency variations due to the expansion produced by the heating of the walls of a cavity resonator, it is recommended that (a) the sphere be clamped between two diametrically applied supports whose spacing does not change with temperature; the electric dipoles must be radial at the supports; and (b) the sphere be clamped in a ring whose diameter is independent of temperature and the electric dipoles be arranged diametrically in the plane of the ring and in a radial direction. See also 3208 and 3209 (Niessen).

621.396.611.1 3211
Characteristic Oscillations of Solid Conductors and Electromagnetic Cavities—P. Nicolas. (*Ann. Radioélect.*, vol. 1, pp. 181–190; January, 1946.) The periodic oscillations of a solid body or of a cavity are studied for the case of any shape. It is shown that there are preferred modes of oscillation which lead to particularly simple relations between the fields and currents. There is generally no geometrical relationship between the current distributions corresponding to two different characteristic modes. In general, on any surface, there are no preferred co-ordinates which lead to simplified relations between the fields and currents. The current distributions corresponding to free oscillations are closely connected with the characteristic modes. When a hollow resonator or a solid conductor is used it is almost always in the vicinity of one of its frequencies of free oscillation. It can be assumed that one of the characteristic modes of distribution preponderates and that the properties mentioned applied to the whole current-system in practice. All these results have been obtained by starting from the reciprocity theorem of electromagnetism.

621.396.611.1:534.13 3212
The Equivalent Circuit of a Spherical Vibrator—Sacerdote. (*See* 3160.)

621.396.611.1.017 3213
D* and *Q—R. F. Field. (*Gen. Radio. Exp.*, vol. 20, pp. 5–8; May, 1946.) Expressions for power losses in a reactor are given in terms of the storage factor Q, or its reciprocal D, the dissipation factor. Exclusive use of the latter is recommended, particularly where more than one source of loss is present.

621.396.615 3214
Synchronization and Frequency Division—N. Carrara. (*Alta Frequenza*, vol. 14, pp. 134–160; September–December, 1945. With English, French, and German summaries.) A general theoretical treatment of a resonant circuit connected to a two-terminal negative-resistance element. The condition for oscillation is established, and the system is classified as real or complex according as the discriminant of the second-order differential equation for the system is positive or negative. The synchronization and frequency-division characteristics of these types are separately considered, and the optimum conditions of operation are deduced. Oscillograms of the synchronizing process in a "real" oscillator are given.

621.396.615.029.63 3215
Composite Tank Circuit for U.H.F.—P. L. Bargellini. (*Electronics*, vol. 19, pp. 115–119; September, 1946.) A description of circuits, each comprising a resonant transmission line inside a resonant cavity, for use with negative-grid triodes. The arrangement gives a greater maximum frequency of oscillation, greater stability and greater ease of coupling to the load than is obtained with an ordinary transmission-line circuit. For an earlier paper by the same author dealing with the same material, see *Alta Frequenza*, vol. 14, pp. 161–174; September–December, 1945.

621.396.615.1 3216
Oscillator Power Relations—R. E. Burgess. (*Wireless Eng.*, vol. 23, pp. 237–240; September, 1946.) "The amplitude and power relations are derived for a class of valve-maintained oscillators in which the source of power can be represented as a negative-conductance element which has a characteristic limited by a term proportional to a higher odd-power of the voltage. The analysis is based on the classical work of E. V. Appleton and B. van der Pol. The coupling conditions for obtaining the maximum output power from such a source are deduced and shown to differ fundamentally from the impedance-match conditions appropriate to linear systems. It is shown that the intrinsic oscillator-circuit losses are purely parasitic in the transfer of power to an external load-circuit, and there is no question of a resistance match.

"The response of such an oscillator circuit to a small external electromotive force having a frequency different from the oscillation frequency is considered. It is found that the circuit effectively has a positive conductance which is proportional to the excess negative conductance producing oscillation."

621.396.615[.11+.17 3217
Low-Frequency Oscillator Using an Artificial Electric Line—M. Federici. (*Alta Frequenza*, vol. 14, pp. 175–182; September–December, 1945. With English, French, and German summaries.) A low-pass line having 100 sections (40 millihenry series, 0.01 microfarad shunt) with a cut-off frequency of 16 kilocycles is used as the feedback element of a triode circuit. The fundamental frequency of oscillation is 250 or 500 cycles according as the coupling transformer gives a phase shift of 0 or π. Oscillographic analysis of the wave form shows appreciable harmonic content. A four-section lattice network (130 millihenry series, 0.5 microfarad shunt) having a markedly nonlinear phase versus frequency characteristic shows that synchronization between the various constituent frequencies need not occur, e.g., in a typical case frequencies of 247 and 1400 cycles were present. The oscillator can, therefore, be used to produce complex wave forms for special purposes.

621.396.615.11 3218
Two-Phase Resistance-Capacitance Oscillator—G. B. Madella. (*Alta Frequenza*, vol. 14, pp. 5–10; March–June, 1945. With English, French, and German summaries.) The circuit uses a single-phase resistance-capacitance oscillator with a phase-shifter mechanically linked with the frequency control of the oscillator to give constant shift at all frequencies. It has the advantages of greater frequency stability and simplicity compared with the beat-frequency oscillator but does not provide such a wide frequency range. The model described has a range of 60 to 300 cycles and a range of 8:1 should be possible by the use of a larger variable capacitor. The distortion of the output voltage is less than 2 per cent.

621.396.615.17 3219
Wave Shaping Circuits—S. Fishman. (*Radio Craft*. vol. 17, pp. 761, 793; August, 1946.) Simple explanation of the action of diode and triode limiters used as square-wave generators.

621.396.615.17:]621.317.755+621.397.331.2 3220
Current Oscillator for Television Sweep—G. C. Sziklai. (*Electronics*, vol. 19, pp. 120–123; September, 1946.) The inadequacies of previous saw-tooth current oscillators for magnetic deflection are reviewed, and the basic principles of the requirement are outlined. A circuit is described, with circuit diagrams, which gives a sweep of excellent linearity with adequate amplitude to give full deflection in a 12-inch 38-degree kinescope. Specifications of the oscillator transformer and dual filament choke are given.

621.396.619 3221
Class B Modulator Design—R. M. W. Grant. (*Marconi Rev.*, vol. 9, pp. 70–87; April–June, 1946.) A theoretical discussion of the design of the output filter generally used with high-power class-B modulators.

621.396.621.029.64 3222
Low Noise Microwave Video Receiver Design—Zable. (*See* 3407.)

621.396.645 3223
Design of Broad Band I.F. Amplifiers—R. F. Baum. (*Jour. Appl. Phys.*, vol. 17, pp. 519–529; June, 1946.) A treatment of the problem for stagger-tuned stages, each consisting of a single-tuned circuit, with an extension to the case of stages containing two magnetically coupled circuits. "It is found that the figure of merit (Q_n) of the individual circuits should be related to the Q of a reference circuit according to:

$$Q/Q^n = \sin[(2m+1)\pi/2t]\cdot\frac{\omega_0}{\omega_{0n}},$$
$$m = 0, 1, 2, \cdots (t-1).$$

Then, by proper tuning, either an oscillatory or a monotonic response may be obtained. The relative bandwidth BW/f_0 and the gain tolerance d_0 within the band determines the value of Q. The minimum number of stages for a given minimum attenuation in the cutoff region depends only on the gain tolerance and on the desired kind of response. Gain maxima (attenuation minima) appear at frequency deviations $\Delta f_n^{\min}$ from middle-band frequency f_0 given by:

$$2\Delta f_n^{\min}/BW = \cos[(2m+1)\pi/2t].$$

Their location depends only on the number of stages. The resonance deviation Δf_{0n} of the tuned circuits are proportional to $\Delta f_n^{\min}$ with a proportionality factor F dependent on t and d_0. The circuit impedances are calculated from a prescribed gain or from the maximum attainable gain. A formula for the maximum gain bandwidth product is derived."

621.396.662.2 3224
Tracking Permeability-Tuned Circuits—A. W. Simon. (*Electronics*, vol. 19, p. 138; September, 1946.) A brief account of the theory, with worked-out examples.

621.396.662.34:621.396.611.21 3225
Generalized Curves for the Design of the Two-Crystal Bandpass Filter—J. D. Brailsford. (*Marconi Rev.*, vol. 9, pp. 40–63; April–June, 1946.) Development of a design technique. The curves give the transmission loss of the filter used as an interstage coupling. The effect of crystal mismatching is taken into account, and a note is included on the use of mechanically coupled crystals.

621.396.665 3226
Surgeless Volume Expander—A. N. Butz, Jr. (*Electronics*, vol. 19, pp. 140, 142; September, 1946.) Description of a circuit which balances out anode-current surges without recourse to push-pull operation.

621.396.667 3227
Tone Control Circuits—Wortman. (*See* 3170.)

621.397.813 3228
Theoretical Investigation of the Distortion of Television Signals in Valve Circuits—J. Huber. (*Schweiz. Arch. Angew. Wiss. Tech.*, vol. 11, pp. 115–127; April, 1945.) Conclusion of 901 of April.

GENERAL PHYSICS

53.081 3229
A Discussion on Units and Standards—(*See* 3341.)

531.3 3230
On the Process of Establishment of Oscillatory Systems with One Degree of Freedom—V. V. Kasakevitch. (*Compt. Rend. Acad. Sci.* (U.R.S.S.), vol. 49, pp. 486–489; December 10, 1945. In French.)

535.1 3231
Change of Frequency of a Light Wave by the Variation of its Optical Path—T. L. Ho and W. S. Lung. (*Nature* (London), vol. 158, p. 63; July 13, 1946.) A formula is derived and applied to various types of waves; application to material waves gives confirmation of the relation $E = h\nu$, and represents one type of energy change for photons. A more generalized formula is proposed which represents a second type of energy change, and which also explains the effect on frequency of a doubly refracting medium.

535.215+621.383 3232
Influence of Polarized Light on the Falling-Off Effect of the Limiting Potential of Einstein's Photoelectric Law.—E. Marx. (*Phys. Rev.*, vol. 69, pp. 523–529; May 1–15, 1946.)

535.34 3233
Nuclear Electric Quadrupole Moment and the Radiofrequency Spectra of Homonuclear Diatomic Molecules—B. T. Feld. (*Phys. Rev.*, vol. 70, p. 112; July 1–15, 1946.) Abstract of an American Physical Society paper.

535.343.4+621.396.11.029.64+538.569.4 3234
The Absorption of Microwaves by Gases—W. D. Hershberger. (*Jour. Appl. Phys.*, vol. 17, pp. 495–500; June, 1946.) The full paper, of which an abstract was noted in 1336 of May. Fourteen gases including ammonia, dimethyl ether, various amines, and alkyl halides have shown strong absorptions at microwavelengths. Measurements of the absorption coefficient and permittivity of these at 1.25-centimeter wavelength and atmospheric temperature and pressure are given. The frequencies for maximum absorption are derived from absorption versus pressure curves. Data on the absorption

of several gas mixtures are given, and possibly molecular mechanisms are discussed. See also 3235, 3236, 3238, and back references.

535.343.4+621.396.11.029.64 3235

Expected Absorption in the Microwave Region by Water Vapor and Similar Molecules—R. M. Hainer G. W. King and P. C. Cross. (*Phys. Rev.*, vol. 70, pp. 108–109; July 1–15, 1946.) "To predict microwave absorption it is necessary to determine all possible transitions [up to $J\sim 12$] between asymmetric rotor levels about one wave number apart.... Exact values of the energies and transition probabilities of H_2O were calculated and the position and intensity of absorption in the microwave region determined." The work has been extended to D_2O, HDO, H_2S, H_2Se, D_2Se. See also 3234. Abstract of an American Physical Society paper.

535.343.4 + 621.317.011.5 + 621.396.11.029.64] :546.171.1 3236

The Inversion Spectrum of Ammonia—W. E. Good. (*Phys. Rev.*, vol. 69, p. 539; May, 1–15, 1946.) The strong absorption band of NH_3 at 0.8 centimeter^{-1} has been resolved into 28 sharp, widely separated lines, using a variable-frequency continuous-wave source. A graph of the frequencies and intensities of the lines is given, and the empirical expression for the frequencies compared with previous theoretical and experimental results. The lines were observed at about 0.1 millimeter of mercury pressure by inserting the gas in a wave guide between a frequency-modulated source and detectors connected to a cathode-ray display. A hyperfine structure is resolved at about 10^{-2} millimeters of mercury pressure. For an abstract of an American Physical Society paper based on this work see *Phys. Rev.*, vol. 70, p. 109; July 1–15, 1946. See also 2622 of September (Bleaney and Penrose), and back reference.

535.343.4+621.317.1.011.5+621.396.11.029.64] :546.171.1 3237

Ammonia Spectrum in the 1 cm. Wavelength Region—B. Bleaney and R. P. Penrose. The cross reference to this paper given in 2536 of September as "*See* 2662" should read "*See* 2622."

535.343.4+621.396.11.029.64]:546.171.1 3238

Resolution and Pressure Broadening of the Ammonia Spectrum Near One-cm. Wave-Length—C. H. Townes. (*Phys. Rev.*, vol. 70, p. 109; July 1–15, 1946.) Twelve lines were resolved and examined in the band 22,840 to 25,046 megacycles at pressures less than 1 millimeter of mercury. Detailed examination of one line yielded a collision frequency of 1.7×10^{8} seconds^{-1}. See also 3236 and back references. Abstract of an American Physical Society paper.

535.343.4:535.61–15:546.212.02 3239

The Infra-Red Spectrum of Heavy Water—F. P. Dickey and H. H. Nielsen. (*Phys. Rev.*, vol. 70, p. 109; July 1–15, 1946.) Abstract of an American Physical Society paper.

535.376 3240

Cathodo-Luminescence: Part 1—Growth and Decay Processes: Part 2—Current Saturation and Voltage Effects: Part 3—Discussion of Results—J. W. Strange and S. T. Henderson. (*Proc. Phys. Soc.*, vol. 58, pp. 369–383, 383–391, and 392–401; July 1, 1946.) Experimental results show that processes of exponential form occur widely in growth and decay of light output from inorganic phosphors. The simple theory relating to monomolecular or random-type processes fails to account for the complexity of the results. There is no definite evidence in favor of bimolecular decay, though nonexponential processes are found to be present in the growth at low current densities and in the decay at long times after excitation.

Measurements have been made of the light output from phosphors under steady electron beams at constant voltage and varying current density, and "current saturation" has been found to vary greatly in extent for different materials. Similarly the change of light output with varying voltage at constant current density shows different characteristics for different phosphors, but without the expected variation on changing the current density.

The interpretation of the experimental results is inadequate, due to insufficient knowledge of electron absorption in phosphors. There is some evidence of a new type of voltage absorption law.

536.4+536.5 3241

A New Form of Chart for Determining Temperatures in Bodies of Regular Shape During Heating or Cooling—A. J. Ede. (*Phil. Mag.*, vol. 36, pp. 845–851; December, 1945.)

537.122:[537.212+538.12 3242

On a Free Electron Gas in Static Magnetic and Electric Fields—J. Lindhard. (*Ark. Mat. Astr. Fys.*, vol. 33, part 1, section A, 17 pp; August 26, 1946. In English.) A theoretical paper.

537.221 3243

Contact Potential Difference in Crystal Rectifiers—Meyerhof. (*See* 3465).

537.228.1 3244

Forced Vibrations of Piezoelectric Crystals—H. Ekstein. (*Phys. Rev.*, vol. 70, pp. 76–84; July 1–15, 1946.) "The vibrations of anisotropic bodies under the influence of sinusoidally variable volume forces and boundary stresses are investigated. The displacement components are represented as sums of a system of "zero-order" solutions which solve approximately the free-vibration problem. By using Betti's theorem, the problem is reduced to a system of inhomogeneous linear equations which, for the free-body case, further reduces to the homogeneous system derived in an earlier paper. If the external forces are piezoelectric, the forces are no longer given explicitly because the electrical field distribution is known only if Maxwell's equations are solved simultaneously. However, if the pertinent piezoelectric constants are small, the field can be calculated approximately as if the crystal were not vibrating. The solutions can then be obtained by the above method, and the electric reaction of the crystal upon the driving system can be determined. As an example, forced vibrations of thin quartz plates between parallel electrodes are discussed."

For previous work by the author, see 523 and 3645 of 1945.

537.533.72+621.385.833 3245

The Variation of Resolution with Voltage in the Magnetic Electron Microscope—V. E. Cosslett. (*Proc. Phys. Soc.*, vol. 58, pp. 443–455; July 1, 1946.) A theoretical consideration of spherical and chromatic aberrations, diffraction error, and total error. The calculations indicate that there are definite optimum conditions of operation for a given lens.

537.56:621.396.11 3246

Conduction and Dispersion of Ionized Gases at High Frequencies—H. Margenau. (*Phys. Rev.*, vol. 69, pp. 508–513; May 1–15, 1946.) "The distribution in energy of electrons in a high-frequency electromagnetic field is derived by kinetic theory methods. By use of the distribution law, the current density and hence the (complex) conductivity are calculated as functions of electron density, pressure, and frequency of the field. The real part of the conductivity has a maximum for gas pressures, or frequencies, such that the mean free time of an electron is approximately equal to the period of the field. From the conductivity, the dielectric constant of the medium, its index of refraction, and its extinction coefficient are deduced. The results are applicable in microwave researches and in ionosphere problems."

538 3247

Unipolar Magnetic Charges (Poles)—F. Ehrenhaft. (*Phys. Rev.*, vol. 70, p. 114; July 1–15, 1946.) Abstract of an American Physical Society paper.

538.114 3248

Magneto-Resistance and Domain Theory—R. M. Bozorth. (*Phys. Rev.*, vol. 70, p. 106; July 1–15, 1946.) "Changes in resistivity at saturation in longitudinal and transverse fields have been measured for alloys containing 40 to 100 per cent nickel, and these are compared with the changes due to tension." Abstract of an American Physical Society paper.

538.12 3249

A New General Theory of the [Magnetic] Coercive Field—L. Néel. (*Compt. Rend. Acad. Sci.* (Paris), vol. 223, pp. 198–199; July 22, 1946.)

538.14 3250

Magnetic Domain Patterns on Silicon-Iron Crystals—H. J. Williams. (*Phys. Rev.*, vol. 70, July 1–15, 1946.) Abstract of an American Physical Society paper.

538.247 3251

The Demagnetizing Factors for Ellipsoids—E. C. Stoner. (*Phil. Mag.*, vol. 36, pp. 803–821; December, 1945.)

538.3:530.12 3252

Relative Nature of Electromagnetic Radiation—H.-P. Soh, M.-H. Wang, and S.-C. Kiang. (*Nature* (London), vol. 157, p. 809; June 15, 1946.)

538.32:621.385.832 3253

An Analysis of Electromagnetic Forces—A. Gronner. (*Elec. Eng.* vol. 65, pp. 300–302; June, 1946.) A letter commenting on 587 of March (Tripp) explaining the forces between electrons in parallel motion in terms of relativity theory. See also 2547 of September (Burgess: G.W.O.H.)

538.652 3254

The Effect of Transverse Magnetic Field on the Longitudinal Joule Magnetostriction Effect in Nickel—O. P. Sharma. (*Indian Jour. Phys.*, vol. 19, pp. 202–209; October, 1945.) The effect predicted by Williams (*Phys. Rev.*, vol. 34, p. 289; 1912), that a transverse field would produce an additional change in length of a longitudinally magnetized rod is confirmed experimentally.

539.3 3255

Impedance Representation of Tangential Boundary Conditions—G. D. Camp. (*Phys. Rev.*, vol. 69, pp. 501–502; May 1–15, 1946.) The tensor formulation of an elastic system is given, and the method applied to the tangential impedance for the plane boundary of a viscous fluid.

548.0:547.476.3–162 3256

Structure and Thermal Properties of Crystals:—Part 6—The Role of Hydrogen Bonds in Rochelle Salt—A. R. Ubbelohde and I. Woodward. (*Proc. Roy. Soc. A*, vol. 185, pp. 448–465; April 5, 1946.)

621.317.39:535.34 3257

The Measurement of Nuclear Spin, Magnetic Moment, and Hyperfine Structure Separation by Microwave Frequency-Modulation Method—Roberts, Beers, and Hill. (*See* 3347.)

621.317.39.029.64:537.312.62:546.815–1 3258
Superconductivity of Lead at 3-cm. Wave-Length—F. Bitter, J. B. Garrison, J. Halpern, E. Maxwell, J. C. Slater, and C. F. Squire. (*Phys. Rev.*, vol. 70, pp. 97–98; July 1–15, 1946.) Outline of experiments and equipment used at a wavelength of 3.2 centimeters. The lead sample was in the form of a resonant cavity, the Q of which was measured by taking resonance curves using the variable-frequency signal from a medium-wave generator mixed with the output from a stabilized klystron as the signal source. "The best indications . . . indicate a conductivity at 4 degrees Kelvin of 10^6 times as great as at room temperature. . . ." The values of Q measured were of the order of 10^4.

621.384 3259
The Stability of Synchrotron Orbits—Dennison and Berlin. (*See* 3466.)

621.384 3260
The Racetrack: a Proposed Modification of the Synchrotron—H. R. Crane. **The Stability of Orbits in the Racetrack**—D. M. Dennison and T. H. Berlin. (*Phys. Rev.*, vol. 69, pp. 542 and 543; May 1–15, 1946.)

621.385.82 3261
High-Frequency Discharge as an Ion Source—P. C. Thonemann. (*Nature* (London), vol. 158, p. 61; July 13, 1946.) A 10-milliangstrom current of positive hydrogen ions has been drawn from a high-frequency discharge and focused into a beam by a direct potential difference of 20 kilovolts. Use of a magnetic field may increase the current.

621.392:[534+535 3262
Extension of the Characteristic-Impedance Concept to Acoustics, Optics, and to the Theory of Vibrating Strings—F. Bedeau, (*Rev. Tech. Comp. Franç. Thomson-Houston.* pp. 21–30; April, 1946.) A generalized treatment of characteristic impedance z arrived at independently of Schelkunoff's work (1740 of 1938). The z for a longitudinal sound wave is given by $\sqrt{\rho E}$ (ρ = density of medium, E = elasticity), and, for a transverse sound wave, as for a vibrating string, by $\sqrt{\mu\tau}$ (μ = mass per unit length, τ = tension). In electromagnetic units the characteristic impedance and velocity of waves in a transparent medium are equal. The application of these concepts to acoustical and optical problems is illustrated.

621.395.822:621.315.59 3263
Electrical Contact Noise—M. H. Greenblatt, P. H. Miller, Jr., and L. I. Schiff. (*Phys. Rev.*, vol. 70, p. 113; July 1–15, 1946.) A theory is given of the low-frequency noise observed in biased electrical contacts involving semiconductors, based on diffusion of impurities between semiconductor and interface region where large electric fields exist. Preliminary experiments give confirmation of the theory on variation of noise power with frequency, back-bias current, and temperature. Abstract of an American Physical Society paper.

621.396.029.64 3264
Elementary Physics of Ultra-Short Waves—P. Grivet. (*Onde Élect.*, vol. 26, pp. 135–148 and 188–203; April and May, 1946.) A survey of the special characteristics of centimeter waves and of the theory of their generation by triode and velocity-modulated tubes, with detailed description of typical tubes. The second section gives a general account of guided waves and of horn types of radiator. Appendices give more detail of the theory of electron beams, of dielectric losses, and of attenuation. In particular, a development of guided-wave phenomena in terms of the interference patterns arising from reflections from the walls of the guide is given. Bibliography of 55 items.

621.396.611 3265
Electromagnetic Field in Cavity Resonators—M. Abele (*Alta Frequenza*, vol. 14, pp. 96–116; March–June, 1945.) With English, French, and German summaries.) A general analysis of the field inside cavities bounded by surfaces of revolution, neglecting dielectric and ohmic losses. Only those cases are considered in which no meridian plane is a nodal plane both for the electric and for the magnetic field. The location of the points of zero electric field is indicated, and enables the qualitative configuration of the field to be rapidly determined. The theory is applied to the behavior of a toric and of an almost cylindrical cavity at their fundamental modes.

621.396.822+537.525.5]:621.385 3266
Noise and Oscillations in Hot-Cathode Arcs—J. D. Cobine and C. J. Gallagher. (*Phys. Rev.*, vol. 70, p. 113; July 1–15, 1946.) Positive ions oscillate in two regions of the discharge, the plasma, the potential minimum at the cathode; the disturbances appear as voltage variations between the electrodes. "Plasma" oscillations are usually below 400 kilocycles and "cathode" oscillations 700 kilocycles. Random noise depends on current, increasing rapidly as Townsend discharge changes into an arc. Noise voltage was investigated under various conditions by a probe technique. See also 3267. Abstract of an American Physical Society paper.

621.396.822+537.525.5]:621.385 3267
Effect of Magnetic Field on Noise and Oscillations in Hot-Cathode Arcs—C. J. Gallagher and J. D. Cobine. (*Phys. Rev.*, vol. 70, p. 113; July 1–15, 1946.) Oscillations in gas discharges discussed in 3266 above are affected by a magnetic field transverse to the normal flow of currents. Oscillations are transmitted to the electrodes by electrons velocity modulated by the plasma oscillations. A critical value of field suppresses oscillation and reduces noise to a minimum. Higher values give increased noise above 1 megacycle. Abstract of an American Physical Society paper.

621.396.822 3268
Statistical Analysis of Spontaneous Electrical Fluctuations—Fürth and MacDonald. (*See* 3411.)

53:621.38 3269
Traité de Physique Electronique [Book Review]—L. Chrétien. C. Chiron, Paris, 368 pp. (*Onde Élect.*, vol. 26, p. 17A, June, 1946.) "The fundamentals . . . in popular form . . . Nothing essential is sacrificed."

GEOPHYSICAL AND EXTRA-TERRESTRIAL PHENOMENA

523.16:621.396.822 3270
Cosmic Radiations at 5 Metres Wave-Length—J. S. Hey, J. W. Phillips and S. J. Parsons. (*Nature* (London), vol. 157, pp. 296–297; March 9, 1946.) The intensity distribution of cosmic-noise power-flux at 64 megacycles was measured with a radio receiver using a Yagi aerial system providing a beam width to half power of ±6 degrees in elevation and ±15 degrees in bearing. The results are presented in the form of a contour map. The contours are roughly asymmetrical with respect to the galactic equator. The main source is in the direction of the galactic center, a second peak is at radio active 2030 hours, declination +35 degrees in Cygnus. The intensity in the first peak is given as 13.2×10^{-21} $\Delta\nu\ \Delta\omega$ watts per square inch where $\Delta\nu$ = band-width in cycles and $\Delta\omega$ = solid angle in steradians.

523.16:621.396.822 3271
Interstellar Origin of Cosmic Radiation at Radio-Frequencies—J. L. Greenstein, L. G. Henyey and P. C. Keenan. (*Nature* (London), vol. 157, pp. 805–806; June 15, 1946.) Measurements of the intensity of cosmic electromagnetic radiation (see 1823 to 1826 of July and back references, and 3270 above) show good agreement with computed values based on the theory of radiation arising from free-free transitions by electrons in the field of protons, using the accepted figures for the number of protons and electrons.

523.165:523.3 3272
A Lunar Effect on Cosmic Rays?—A. Duperier. (*Nature* (London), vol. 157, p. 296; March 9, 1946.) Harmonic analysis of average solar daily inequalities reveals the existence of a semi-diurnal variation, nearly opposite in phase to the semi-diurnal barometric oscillation. It is deduced that the moon may, by altering the height of the meson-producing layer, affect the intensity of cosmic rays at ground level.

523.165 3273
Solar and Sidereal Diurnal Variations of Cosmic Rays—A. Duperier. (*Nature* (London), vol. 158, p. 196; August 10, 1946.) Analysis of observations over the last 3 years indicates a seasonal change in the intensity of cosmic radiation. The variation of the time of maximum intensity may also be taken as evidence of a sidereal variation. The maximum and minimum values of the solar variation, 0.77 per cent and 0.06 per cent respectively, may be correlated with the change of solar zenith distance. It is suggested that part of the cosmic radiation may originate in the sun and part in the galaxy.

523.165 3274
The East-West Asymmetry of Cosmic Radiation at a Geomagnetic Latitude of 28°31′ and an Estimation of the Difference of the Exponents of the Absorption Law for the Polar and the Equatorial Regions—F. Oster, S. L. Ch'u and L-Y. Lü. (*Phys. Rev.*, vol. 69, p. 531; May 1–15, 1946.)

523.7 3275
General Magnetic Field of the Sun—T. G. Cowling. (*Nature* (London), vol. 158, p. 31; July 6, 1946.) Abstract of a paper in *Mon. Not. R. Astr. Soc.*, surveying the various theories. The view that the material in the far interior of the sun is capable of permanent magnetization is considered worthy of further investigation.

523.74"1942.02/.03" 3276
Solar Eruption of February–March, 1942—B. Edlén. *Nature* (London), vol. 157, p. 297; March 9, 1946.) Reminder of the decreased cosmic-ray intensity, and the increased intensity of the 5694 angstroms line, produced on this occasion.

523.78:[551.51.053.5+621.396.11 3277
The Solar Eclipse of 1945 and the Propagation of Radio Waves—R. L. Smith-Rose. (*Alta Frequenza*, vol. 15, pp. 37–38; March, 1946.) Long summary in Italian of 1831 of July.

551.51.053 3278
Meteorology of the Lower Stratosphere—G. M. B. Dobson, with A. W. Brewer and B. M. Civilong. (*Proc. Roy. Soc. A*, vol. 185, pp. 144–175; February, 1946.) Methods of measuring the amounts of water vapor, carbon dioxide, and ozone in the upper atmosphere are described, and the meteorological conditions at these levels discussed. Bakerian Lecture.

551.51.053.5 3279
Detection of Rapidly Moving Ionospheric Clouds—H. W. Wells, J. M. Watts and D. E. George. (*Phys. Rev.*, vol. 69, pp. 540–541; May 1–15, 1946.) Observations were made during the magnetic storm of March 25 and 26, 1946, with a new panoramic recording technique that

enables the frequency range 1.5 to 20 megacycles to be swept in a time adjustable from 5 to 30 seconds. The ionospheric clouds were observed to move in from 800 to 900 kilometers down to 300 to 400 kilometers at a rate of 1 to 2 kilometers, and sometimes to move out again at a similar rate. "The principal effects of influx of the clouds are: (1) sudden changes in F-layer ionization; (2) rapid changes in F-layer heights indicating turbulence which is often progressive from high to low heights and from high to low frequencies; (3) rapid fluctuations of echoes at the lower frequencies with occasional temporary disappearance indicating high absorption."

The clouds are provisionally attributed to corpuscular ionization during magnetic disturbances, indicating a corpuscular contribution to F-layer ionization. An inaccurate account of these observations was noted in 2889 of October.

551.51.053.5 3280
Geophysics of the Ionosphere—J. W. Cox. (*Nature* (London), vol. 158, pp. 189–191; August 10, 1946.) Report of a discussion at the Royal Astronomical Society. Appleton surveyed the present state of knowledge of the ionosphere layers and pointed out some of the outstanding problems. Mumford spoke on reciprocity of transmission and reception. Kirke described experiments on lateral deviation between Daventry and New Delhi, and also asked that attenuation on long routes and the influence of the gyromagnetic frequency should be further studied. Cox described the wartime work of the (British) Inter-Service Ionospheric Bureau. Hey spoke on solar noise and scatter bursts. Massey spoke on the processes of recombination and attachment.

551.51.053.5:523.746 3281
The Ionosphere as a Measure of Solar Activity—M. L. Phillips. (*Phys. Rev.*, vol. 70, p. 119; July 1–15, 1946.) Critical frequencies (f^0) of regular ionospheric layers vary as $f^0=F_1(t)+F_2(t)S$ where t is time of day, and S the sunspot number. Where ionospheric trends are well established, observations of critical frequency may be used to determine an ionospheric "sunspot number." Using F_2-layer observations around local noon, the ionospheric "sunspot number" probably presents a more precise index of solar activity than the ordinary sunspot number. Abstract of an American Physical Society paper.

LOCATION AND AIDS TO NAVIGATION

534.88 3282
Echo Depth Sounder for Shallow Water—Shaw. (*See* 3163.)

534.88:534.321.9 3283
The "Sonicator." (*See* 3164.)

621.396.677.1 3284
The Mutual Perturbations of Two Loop Direction Finders—F. Penin. (*Onde Élect.*, vol. 26, pp. 101–106; March, 1946.) It is shown that the minimum separation between two direction finders for freedom from errors within a given standard depends on the diameter of the loops, their type of winding, and effective Q values. In particular, it is shown that separation of two or three meters is adequate for the types of direction finder mounted in aircraft.

621.396.9 3285
Radar—E. G. Schneider. (Proc. I.R.E. and Waves and Electrons, vol. 34, pp. 528–578; August, 1946.) A comprehensive survey of the principles, problems, and techniques.

621.396.9 3286
The Scientific Principles of Radiolocation—E. V. Appleton. (*Alta Frequenza*, vol. 14, pp. 230–232; September–December, 1945.) A long summary in Italian of 3777 of 1945.

621.396.9 3287
An Introduction to Hyperbolic Navigation, with Particular Reference to Loran—J. A. Pierce. (*Jour. I.E.E.*, (London), part III, vol. 93, pp. 243–250; July, 1946.) "Hyperbolic navigation is achieved when synchronized signals, having a known velocity of propagation are transmitted from at least three known points, and when the relative times of arrival of these signals are known and measured by a navigator." For loran, pulse transmitters, (frequency 1.70 to 2.00 megacycles) synchronized by ground-wave (standard loran) or sky-wave (SS loran), are at the known points.

The accuracy of standard loran is about 300 yards at short distances and about 1 mile in the ground-wave service area, 700 miles by day, 500 miles by night over sea. For sky-wave working at night the error is 1½ to 8 miles for ranges of 300 to 1400 miles. In SS loran the minimum average error of fix is 0.9 nautical miles due to variations in ionosphere heights. Low-frequency loran, at present under development, should have day or night range of at least 1000 miles but with lower accuracy than standard loran. Summary and I.E.E. discussion of a paper in Proc. I.R.E. and Waves and Electrons.

621.396.9 3288
The Loran System—(*Alta Frequenza*, vol. 15, pp. 48–52; March, 1946.) Long summary in Italian of 605 of March.

621.396.9 3289
The Civil Application of Radar—E. G. Bowen. (*Proc. I.R.E.* (Australia), vol. 7, pp. 4–10; June, 1946.) A short account of applications to civil aviation, marine navigation, surveying, and meteorology. An airborne distance indicator is described for measuring range from an airport, with 2 per cent accuracy up to 120 miles at 8000 feet flying height. A multiple-track radar range (MTR) under development uses the Gee principle (see 3916 of 1945—Harley) but with ground transmitters 5 to 10 miles apart. An aircraft located to ±20 yards relative to two radar beacons 200 miles apart can be used for the photographic surveying of an area of about 200,000 square miles. The importance to the meteorologist of scatter from raindrops is mentioned. For two previous lectures see 1854 of July and 2907 of October.

621.396.9(44) 3290
On French Contributions to the Technique of Electromagnetic Detection [of Objects]—M. Ponte. (*Ann. Radioélect.*, vol. 1, pp. 171–180; January, 1946.) Historical survey of radiolocation developments in France by the C.S.F. (Compagnie Générale de T.S.F.) and the S.F.R. (Société Française Radioélectrique).

In 1935 continuous-wave obstacle detectors on wavelengths of 80 and 16 centimeters were fitted to ships and installed at harbors giving ranges of about 5 kilometers on ship targets.

In 1936 to 1938 higher-power magnetrons and pulse-modulation technique were developed: peak power 10 watts at λ16 centimeters with 6-microsecond pulses.

Later developments included increase of power to 4 kilowatts on λ16 centimeters, use of 1-microsecond pulses, superheterodyne receivers with cathode-ray indication, and horn radiators. A system installed at Toulon in 1942 gave ranges up to 25 kilometers on large ships with an accuracy of 25 meters in range and 2 to 3 degrees in azimuth. Systems on λ3 meters with a peak power of 25 kilowatts were also developed. The paper contains 18 photographs of the systems described.

621.396.9:621.396.932 3291
Radio Aids for Ships—(*Nature* (London), vol. 157, p. 689; May 25, 1946. *Engineering*, (London), vol. 161, pp. 451–452; May 10, 1946.) International meeting, with demonstrations of war-time devices and their peace-time applications. See also *Engineer* (London), vol. 181, p. 527; June 7, 1946, for a fuller description of one of the new models.

621.396.9:621.396.932 3292
The Electronic Navigator—T. Grover and E. C. Kluender. (*Communications*, vol. 26, pp. 30, 39; August, 1946.) Technical description of a 10-centimeter wavelength merchant-ship surface-search and navigational radar with range 200 yards, or less in favorable conditions to 30 miles. Plan-position indicator display is used, and bearings are indicated by a selsyn unit.

621.396.91 3293
Static [Atmospherics] Direction Finder—H. L. Knowles. (*Phys. Rev.*, vol. 69, p. 546; May 1–15, 1946.) An apparatus developed for the United States Army Signal Corps. It consists of the usual crossed-loop aerials feeding twin amplifiers, with cathode-ray tube display, the orientation of the trace giving the azimuth of the incoming signal. The method of determining the position of the storm area by synchronized observations at three stations is discussed. Abstract of an American Physical Society paper.

621.396.931/.933].22.029.5 3294
Better Direction Finder—E. D. Padgett. (*Radio Craft*, vol. 17, pp. 750, 805; August, 1946.) Description of the Simon radioguide, and its United States military version SCR-503-A. For a previous account see 1545 of June.

621.396.933 3295
All-Weather Flying—G.T.M. (*Electronics*, vol. 19, pp. 84–87; September, 1946.) A general review of available radio aids, giving an account of the state of progress towards their adoption for civil flying in the United States.

621.396.933 3296
Aviation Radio—Newstand. (*See* 3425.)

621.396.933.23 3297
Blind Approach System—D. Brice. (*Aeroplane*, vol. 68, pp. 165–167; February 9, 1945.) A general description of the standard beam approach and American radio range systems.

621.396.9 3298
Introduzione alla Radiotelemetria. [Book Review]—U. Tiberio, Editore Rivista Marittima Roma, 1946, 277 pp., 137 figs., 300 Lire. (*Wireless Eng.*, vol. 23, p. 259; September, 1946. *Alta Frequenza*, vol. 15, pp. 62–64; March, 1946.) Introduction to radar.

MATERIALS AND SUBSIDIARY TECHNIQUES

533.5 3299
A Multiple High-Vacuum Valve—R. I. Garrod. (*Jour. Sci. Instr.*, vol. 23, p. 191; August, 1946.) Design details of a tube to permit the simultaneous or independent exhaustion of four separate vacuum sections.

533.5 3300
Leaking and Controlling Small Quantities of Gas—A. S. Husbands. (*Jour. Sci. Instr.*, vol. 23, pp. 190–191; August, 1946.) A method of control of the gas pressure in discharge tubes using a fixed inlet leak (a porous steatite pellet), and a variable needle-type valve in the exhausting tube.

535.37 3301
Effect of Absorption on Decay of Infra-Red Sensitive Phosphors—R. T. Ellickson and W. L. Parker. (*Phys. Rev.*, vol. 69, p. 534; May 1–15, 1946.)

535.371.07:537.531 3302
Microsecond Phosphorescent Decay Periods of X-Ray Fluorescent Screens—F. Marshall. (*Phys. Rev.*, vol. 70, p. 114; July 1–15, 1946.) Abstract of an American Physical Society paper.

535.376 3303
Cathode-Luminescence: Part 1—Growth and Decay Processes: Part 2—Current Saturation and Voltage Effects: Part 3—Discussion of Results—Strange and Henderson. (*See* 3240.)

537.226 3304
Dielectric Properties of Dipolar Solids—H. Fröhlich. (*Proc. Roy. Soc. A*, vol. 185, pp. 399–414; April 5, 1946.) "A quantitative theory of the dielectric properties of crystalline solids consisting of dipolar long-chain molecules is developed (one dipole per molecule). In these solids the dipoles are concentrated in dipolar planes. In the ground state the dipolar planes have a permanent polarization, but usually the polarizations of successive planes have opposite directions. The static dielectric constant rises with increasing temperature up to a critical temperature T_0 and then decreases. At T_0 the substance has a phase transition of the second kind. Comparison with experiments by Muller on a solid ketone lead to good agreement.

"For chains with an even number of *C*-atoms matastable states with a permanent polarization are predicted, and a method to reach these states is discussed.

"The interaction between dipoles plays a predominant role at temperatures below T_0. It is shown that Lorentz's or Onsager's methods are invalid in this temperature range."

539.23:546.74 3305
Resistivity of Thin Nickel Films at Low Temperatures—A. Van Itterbeek and L. De Greve. (*Nature* (London), vol. 158, pp. 100–101; July 20, 1946.) As films thicker than 40 millimicrons cool towards liquid helium temperatures, the resistance passes through a minimum, the temperature at which this minimum occurs being higher the more nearly the thickness approaches to 40 microns.

539.234:535.87 3306
Thermally Evaporated Anti-Reflexion Films—S. Bateson and A. J. Bachmeier. (*Nature* (London), vol. 158, pp. 133–134; July 27, 1946.) The hardness of magnesium-fluoride films on glass is improved by vacuum-baking in preference to air-baking and depends on the type of source and the degassing procedure. It is not affected by length of baking time. Soft coatings are caused by "soft fluoride," i.e. low-velocity molecules and may be eliminated by use of faster pumps and special pellet sources. A similar effect is observed when coating on two surfaces. See also 2598 of September (Bannon).

541.64+679.5]:05 3307
Journal of Polymer Science—(*Nature* (London), vol. 157, p. 475; April 13, 1946.) Publication of new journal of high-polymer research.

546.23 3308
Volume, Internal Energy, and Entropy of Amorphous and Crystalline Selenium—G. Borelius and K. A. Paulson. (*Ark. Mat. Astr. Fys.*, vol. 33, part 1, section A, 16 pp; August 26, 1946. In English.) The values of these quantities and their differences ΔV, ΔU, ΔS, for the two forms of selenium are calculated from new determinations of the thermal expansion α and the heat capacity *C*. There are no real premelting phenomena in selenium, and in the glassy state (below 300 degrees Kelvin) α and *C* have nearly the same values for the amorphous and crystalline forms; it is, therefore, concluded that "the values of ΔV, ΔU and ΔS obtained in the range of the supercooled liquid from 300 to 494 degrees Kelvin are only dependent on the arrangement of the atoms in the liquid, which at each temperature, attains a state of instable equilibrium." These difference values should be of use for testing theories of the structure of the liquid state. For previous work see 3637 and 3638 of 1945 (Borelius *et al.* and Weibull).

549.514.1 3309
Elastic Deficiency and Color of Natural Smoky Quartz—C. Frondel. (*Phys. Rev.*, vol. 69, pp. 543–544; May 1–15, 1946.) An account of experiments on the effect of various types of radiation on the elastic properties of quartz indicated by changes in the frequency of piezoelectric oscillation. The radiation produces an exponential fall in frequency to a saturation value, accompanied by a smoky coloration proportional to the change in frequency. Natural smoky quartz possesses a similar elastic deficiency which can be removed together with the coloration by baking. The effect, which is of the order of 0.01 per cent of frequency, may be repeated reversibly by successive irradiation and baking. These results are relevant to the ascription of the origin of smoky quartz to natural radioactive radiation, but the effects of the artificial and presumed natural radiation differ in some respects. For instance natural smoky specimens have much smaller elastic deficiency in relation to the coloration than those irradiated artifically.

549.514.1 3310
The Breaking up of Single Crystals of Quartz—D. D'Eustachio and S. B. Brody. (*Phys. Rev.* vol. 69, p. 256; March 1–15, 1946.) Quartz wafers prepared by etching from wafers 75 to 100 microns thick are found no longer to be single crystals when they become thinner than 25 microns. Abstract of an American Physical Society paper.

549.514.1 3311
Thermal Recrystallization of Quartz—D. D'Eustachio and S. Greenwald. (*Phys. Rev.*, vol. 69, pp. 532–533; May 1–15, 1946.) A further report on quartz wafers, 25 to 30 microns thick, which, though prepared from single crystals, are no longer single crystals themselves. The wafers are polycrystalline, neighboring crystals being disoriented by one or two degrees. The single crystalline condition may be recovered by heating, and return to the polycrystalline state occurs if the specimen is bent a number of times round a cylindrical rod. For previous work see 3310 above (D'Eustachio and Brody).

549.514.1 3312
Preparation of Synthetic Quartz—N. Wooster and W. A. Wooster. (*Nature* (London), vol. 157, p. 297; March 9, 1946.) Spezia's method has been confirmed but found unsuitable for industrial production. In a new method, perfect but small crystals are produced by heating fused silica in a solution of sodium metasilicate.

621.314.2:621.395:621.316.974 3313
The Magnetic Screening of Telephone Transformers—Nucci. (*See* 3429.)

621.314.632:546.289 3314
The Photo-Diode and Photo-Peak Characteristics in Germanium—S. Benzer. (*Phys. Rev.*, vol. 70, p. 105; July 1–15, 1946.) When certain germanium crystals are touched with a metal point the saturation current depends on the illumination level and temperature. The maximum photo-effect occurs at about 1.3 microns while for white light the sensitivity is several milliamperes per lumen. The peak in the current versus voltage characteristic may be eliminated by raising the temperature or level of illumination sufficiently; this behavior is reversible and may be applied in the design of a trigger photocell. Abstract of an American Physical Society paper.

621.315.58.029.54/.64 3315
The Electrical Properties of Salt-Water Solutions Over the Frequency Range 1–4000 Mc/s—R. Cooper. (*Jour. I.E.E.* (London), part I, vol. 93, p. 358; August, 1946.) Long summary of 1880 of July.

621.315.59 3316
The Energy of Impurity Levels in Semi-Conductors—B. Serin. (*Phys. Rev.*, vol. 70, p. 104; July 1–15, 1946.) Abstract of an American Physical Society paper.

621.315.61+537.226 3317
Dielectrics in Theory and Application—(*Nature* (London), vol. 158, pp. 121–124; July 27, 1946.) A report of discussions at meetings of the Royal Institute of Chemistry with the Institute of Physics, and of the Faraday Society. The former surveyed the fields of physical theory, chemical preparation and industrial applications; the latter dealt with surveys and original papers on the present state and immediate trends of physical-chemical and physical research. Two important contributions were concerned with the theory of the internal field of dielectrics, and with advances in high-frequency dielectric measurements.

621.315.612 3318
Ceramic Dielectrics—D. C. Swanson. (*Phys. Rev.*, vol. 69, p. 546; May 1–15, 1946.) A study of the dielectric properties of certain ceramic alloys having dielectric constants of several thousand and resistivities of 10^6–10^{16} Ω. The materials show marked change in electrical properties with change in temperature and applied voltage. Proper choice of the alloys will give almost any desired electrical property. Abstract of an American Physical Society paper.

621.315.612.4 3319
Dielectric Constants of Some Titanates—P. R. Coursey and K. G. Brand. (*Nature* (London), vol. 157, pp. 297–298; March 9, 1946.) Addition of metallic titanates to a ceramic mix raises the permittivity to peak values as high as 44,000 at a temperature which is characteristic of the material. Solid solutions of two or more titanates exhibit similar properties, a mixture of two showing a linear relation between composition and the temperature of peak permittivity. Capacitors with positive or negative temperature coefficients of capacitance may be constructed with these dielectrics.

621.315.618.2.015.5:621.3.029.64 3320
Lowering of Electrical Breakdown Field Strength at Microwave Frequencies Due to Externally-Applied Magnetic Field—D. Q. Posin. (*Phys. Rev.*, vol. 69, p. 541; May 1–15, 1946.) Studies of 3-centimeter microwave breakdown of air gaps in a waveguide reveal the following effects: (1) a gap on the verge of sparking can be made to spark over by the approach of a permanent magnet; (2) a magnet with small pole face may produce a 20 per cent decrease in the breakdown field strength; (3) a magnet moved rapidly near the gap may lower the breakdown field strength by a factor of 2 or more; (4) no effect is produced by a magnetic field at right angles to the microwave electric vector; and (5) effects (2) and (3) are much diminished when broadface magnets are used. Various possible explanations of the effects are mentioned, but none appears entirely adequate.

621.316.842+621.315.553 3321
Resistance Materials for Standard Re-

sistors—A. Schulze. (*Arch. Tech., Messen*, pp. T46–48; April, 1940.) Survey of electrical, thermal, and mechanical properties of manganin, isabellin (Cu-Mn alloy with Al) and novokonstant (Cu-Mn alloy with Al, Fe). Recommended technique for the construction of standard-resistance windings is described.

621.319.7:621.385 3322
Potentiograms and Electron Trajectories in Electrostatic Fields—A. Pinciroli and M. Panetti. (*Alta Frequenza*, vol. 14, pp. 81–95; March–June, 1945. With English, French and German summaries.) A general review of methods for plotting electrostatic fields is given. The electrolytic tank is considered in detail with an examination of the sources of error. Experimental results for structures typical of tube electrode systems are described.

621.357.7:546.97 3323
Purification of Rhodium Plating Baths—(*Jour. Frank. Inst.*, vol. 242, pp. 64–65; July, 1946.) A note from the National Bureau of Standards on the impurities in rhodium phosphate plating baths that cause imperfect coatings. The addition of potassium ferrocyanide will precipitate the impurities which can then be filtered out.

621.793:546.74 3324
Nickel Plating on Steel by Chemical Reduction—(*Jour. Frank. Inst.*, vol. 242, p. 64; July, 1946.) A short note from the National Bureau of Standards. "The deposition is brought about by the chemical reduction of a solution of a nickel salt with hypophosphites. The reaction is catalyzed by steel and nickel, and deposition of nickel occurs only on the surfaces of these metals."

621.396.6(213) 3325
Deterioration of Radio Equipment in Damp Tropical Climates and Some Measures of Prevention—Healy. (*See* 3502.)

666.3+621.315.612 3326
The Scientific Basis of Modern Applications of Ceramic Raw Materials—W. Steger. (*Chalmers Tekn. Högsk. Handl.*, no. 32, 23 pp.; 1944. In German.) A brief survey of the composition and properties of ceramics in use for technical applications, with some indication of process of manufacture. The materials considered are: (1) systems with one component: silicic acid, aluminium oxide, alkaline earth oxides, other highly refractory oxides, titanium dioxide; (2) binary systems: silicic acid—aluminium oxide, silicic acid—alkaline earth oxides other simple silicates, non-silicate oxide systems; and (3) ternary systems: silicic acid—aluminium oxide—alkali oxides, silicic acid—aluminium oxide—alkaline earth oxides.

666.3 3327
The Evolution of Ceramic Technique in the Laboratories of the Compagnie General de Télégraphie sans Fil (C.S.F.). C.S.F. Processes for the Preparation of High Precision Ceramics—F. Violet and R. Lecuir. (*Ann. Radioélect.*, vol. 1, pp. 152–159 and 242–255; October, 1945 and January, 1946.)

MATHEMATICS

512.37 3328
Approximating Formulae—W. Luchsinger. (*Brown Boveri Rev.*, vol. 32, pp. 238–242; July, 1945.) Simple explanation of methods of fitting algebraic curves to experimentally determined data.

517.432 3329
The Steady-State Operational Calculus—D. L. Waidelich: N. F. Riordan. (Proc. I.R.E. and Waves and Electrons, vol. 34, pp. 579–580; August, 1946.) Discussion of 1276 of May (Waidelich).

517.942 3330
On Stokes Functions—P. G. Bordoni. (*Alta Frequenza*, vol. 14, p. 227; September–December, 1945.) Abstract of a paper from *Commentationes Pont. Acad. Sci.* (Vatican City) vol. 9, pp. 87–113; 1945, which includes tables and graphs of the first, second, and third order functions useful in acoustical problems.

518.2 3331
Integration of $\sin^2 x\, dx/x$—S. M. Christian. (*Phys. Rev.*, vol. 69, p. 546; May 1–15, 1946.) Notice of the preparation of table of values of the definite integral, from 0 to x. Typical values are given for x in the range 0.5 to 11. Abstract of an American Physical Society paper.

518.3 3332
Nomograph Construction: Part 2—Charts with Complicating Factors or Constants—F. Schunaman. (*Radio Craft*, vol. 17, pp. 690, 719; July, 1946.) For part 1 see 2830 of October.

518.5 3333
An Improved Slide Rule for the Addition of Squares—B. H. Dawson. (*Science*, vol. 104, p. 18; July 5, 1946.) A modification of Morrell's method (2616 of September) using a pair of scales instead of a single scale. See also 2956 of October (Dempster).

518.61 3334
On a New Method of Approximate Integration of Second Order Differential Equations—F. Rabinovitch. (*Ann. Radioélect.*, vol. 1, pp. 134–151; October, 1945.) "This method, based on extrapolation, is a generalized extension of Adams' method for equations of the first order. It embraces as particular cases most of the classical methods of approximate integration, notably Störmer's. The new method is applied to the equation $d^2x/dt^2 = f(x) \sin t$ occurring in the study of the motion of a particle in an oscillating field of force. Formulas for approximate integration, and estimates of the resulting errors are given.

"The treatment concludes with a comparison of the new method and Störmer's for some numerical cases related to the problem of electron motion in a nonuniform high-frequency field." Corrections are given in *Ann. Radioélect.*, vol. 1, p. 276; January, 1946.

519.283:53.08 3335
Experimental Data and 'Sufficient' Accuracy—H. A. Hughes. (*Nature* (London), vol. 158, p. 29; July 6, 1946.) Using the formula $\alpha = 0.6745\sqrt{[\Sigma(x_n - M)^2/n(n-1)]}$ to obtain the most probable error α of the arithmetic mean of a series of n distance-measurements $x_1 \cdots x_n$ it was found that at least 7 observations were necessary to get M to within 2 per cent in one case. 10 was regarded as a safer minimum in general.

519.283:621.318.572 3336
On the Statistical Treatment of Counting Experiments in Nuclear Physics—N. Hole. (*Ark. Mat. Astr. Fys.*, vol. 33, part 2, section A, 11 pp.; August 30, 1946. In English.) Formulas are developed for the statistical distribution of the time intervals between impulses observed on counting apparatus, and the influence of the recovery time ("resolving power") of the counter is considered theoretically. The case of a pair of counters in cascade is also treated.

51(075):62 3337
Engineering Mathematics. [Book Review]—H. Sohon. D. Van Nostrand Co. Inc., New York, 1944. (*Jour. Appl. Phys.*, vol. 17, p. 536; June, 1946.) The book "is intended to strengthen the student in algebra and to provide him with certain mathematical tools which depend on the calculus." See also 2236 of August.

51(075):621.396 3338
Basic Mathematics for Radio Students. [Book Review]—F. M. Colebrook. Iliffe, London, 270 pp., 10s.6d. (*Nature* (London), vol. 158, p. 254; August 24, 1946; *R.S.G.B. Bull.*, vol. 22, p. 45; September, 1946; *Elect. Rev.*, (London), vol. 139, p. 144; July 26, 1946.) "[The author] has rendered a valuable service to students and engineers alike . . . " " . . . substantial gap in the literature for teaching potential engineers has been filled."

518.2:016 3339
An Index of Mathematical Tables. [Book Review]—A. Fletcher, J. C. P. Miller, and L. Rosenhead. Scientific Computing Service, London, 451 pp., 75s. (*Elec. Rev.* (London), vol. 139, p. 388; September 6, 1946; *Proc. Phys. Soc.*, vol. 58, pp. 491–492; July 1, 1946.) Aim is to provide "a working tool for the working scientist in a wide variety of investigations."

519.2(075.8) 3340
Elementary Statistics. [Book Review]—H. Levy and E. E. Preidel. Ronald Press Co., New York, 1945, 184 pp., $2.25. (*Jour. Appl. Phys.*, vol. 17, pp. 535–536; June, 1946.) " . . . an introduction to more advanced texts, and, as such, should contribute to the growing use of statistical methods."

MEASUREMENTS AND TEST GEAR

53.081 3341
A Discussion on Units and Standards—(*Proc. Roy. Soc. A*, vol. 186, pp. 149–217; July 9, 1946.) A symposium of short papers by staff of the National Physical Laboratory on units and standards studied at the Laboratory. Each paper gives the main technical details and a short history.

621.316.842+621.315.553 3342
Resistance Materials for Standard Resistors—Schulze. (*See* 3311.)

621.317.083.7 3343
Telemetering Equipments for the Transmission of Any Desired Measurements Over Long Distances—F. Jaggi. (*Brown Boveri Rev.*, vol. 32, pp. 147–148; April, 1945.) A short account of a system using a variable audio frequency for remote indication.

621.317.1.011.5+621.396.11.029.64+535.343.4]:546.171.1 3344
The Inversion Spectrum of Ammonia—Good. (*See* 3236.)

621.317.333.4 3345
Two Methods of Localising Cable Faults—J. M. Allan. (*P. O. Elec. Eng., Jour.*, vol. 39, part 2, pp. 70–72; July, 1946.) A modification of the Varley test which nullifies the disturbing effects of varying induced currents, and a method of testing when no good wire is available.

621.317.334/.335]:621.315.2 3346
Measurement of Inductance and Capacitance of Conductors and Cables—O. Naumann. (*Arch. Tech. Messen*, pp. T63–65; June, 1940.) Survey of direct-current methods of measurement (Thomson comparison method, "shared charge" method, Sauty bridge), and of low-frequency methods (Wheatstone bridge, Maxwell bridge, Geyger's compensation circuit, Wien and Wien-Wagner bridge and its derivatives, Felten and Guilleaume's impedance bridge).

621.317.39:535.34 3347
The Measurement of Nuclear Spin, Magnetic Moment, and Hyperfine Structure Separation by a Microwave Frequency-Modulation Method—A. Roberts, Y. Beers and A. G. Hill. (*Phys. Rev.*, vol. 70, p. 112; July 1–15, 1946.) Abstract of an American Physical Society paper.

621.317.39.029.64:537.312.62:546.815–1 3348
Superconductivity of Lead at 3-Cm Wave-Length—Bitter, Garrison, Halpern, Maxwell, Salter, and Square. (*See* 3258.)

621.317.4 3349
Some Uses of the Magnetic Potentiometer for the Determination of Magnetization Curves upon Open-Circuited Specimens—T. A. Margerison and W. Sucksmith. (*Jour. Sci. Instr.*, vol. 23, pp. 182–184; August, 1946.)

621.317.71/.72]:621.314.632 3350
Moving-Coil Rectifier Instruments for A.C. Measurements: Part 1—Equivalent Circuit Diagram and Temperature Errors: Part 2—Frequency Error, Back-Current Error, Ageing Error and Waveform Error—K. Maier. (*Arch. Tech. Messen*, pp. T57 and T69–70; May and June, 1940.)

621.317.7 3351
Electrical Measuring Instruments—F. E. J. Ockenden and D. C. Gall. (*Jour. I.E.E.* (London), part I, vol. 93, pp. 348–354; August, 1946.) A review of progress during the past decade, discussing the design and construction of industrial instruments and the wide applications of electrical and electronic instruments to scientific measurement.

621.317.725 3352
An Electrostatic Generating Voltmeter for Measurement of Very Small E.M.Fs.—S. A Scherbatskoy and R. E. Fearon. (*Phys. Rev.*, vol. 70, p. 96; July 1–15, 1946.) Short notes describing a null instrument having good long-term zero stability and "nearly complete immunity to mechanical or thermal abuse." Ionization currents of as low as 10^{-19} ampere "or better" can be measured.

621.317.75.087.5:522.5 3353
On the Registration of the Exact Time of Each Exposure by Cinematographic Photography—K. G. Malmquist, H. Norinder and W. Stoffregen. (*Ark. Mat. Astr. Fys.*, vol. 33, part 1, section B, 7 pp.; August 26, 1946.) In English.) The exact time of exposure of film is measured by means of a double cathode-ray tube. The method is of use for solar eclipse observations.

621.317.761 3354
A Standard-Frequency Generator for High-Precision Measurements—M. Boella. (*Alta Frequenza*, vol. 14, pp. 183–194; September-December, 1945. With English, French, and German summaries.) A laboratory equipment based on a quartz oscillator at 100 kilocycles giving a series of over 55,000 single standard frequencies between 10 kilocycles and 30 megacycles. The interval in this range varies from 3 kilocycles at the high-frequency end to 2 cycles at the low end. With an interpolating low-frequency meter the measurement of a radio frequency can be carried out to a precision not less than 10^4 times that of the interpolator.

621.317.79 3355
Constructing a Grip Dip Meter—H. Burgess (*Radio News*, vol. 36, pp. 50–51; August, 1946.) Constructional details of a test instrument comprising a variable-frequency oscillator with a mixer tube, and with a milliammeter connected in its grid lead. It can be used as a simple signal generator or frequency meter.

621.317.79:621.385.1 3356
Tube Checker Modernizer—H. A. Forter. (*Radio Craft*, vol. 17, pp. 753–803; August, 1946.) Constructional details of an additional panel which may be added to an existing tube testor to make it suitable for testing modern tubes.

621.317.79:621.396.621 3357
Output Systems of Signal Generators—A. Peterson. (*Gen. Radio Exp.*, vol. 21, pp. 1–8; June, 1946.) Discussion of errors in measurement, particularly at frequencies of 5 to 30 megacycles, due to the form of the output circuit and lead. Four arrangements are considered analytically in which the line is either (a) matched at both ends, (b) matched at the generator end, (c) matched at the load end, or (d) unmatched. The output electromotive force and impedance are presented in graphical form as a function of frequency.

621.317.79:621.396.621 3358
The Transigenerator—R. E. Altomare. (*Radio Craft*, vol. 17, pp. 686, 722; July, 1946.) Constructional details of a simple transitron signal generator for the range 160 kilocycles to 8 megacycles.

621.392 3359
The Relation between Nodal Positions and Standing Wave Ratio in a Composite Transmission System—Feenberg. (*See* 3175.)

621.392:621.317.33.029.64 3360
The Use of the Impedance Concept as Applied to Wave Guides—Williams and Bolton. (*See* 3178.)

621.396.24.029.63 3361
Development Work in the Decimetre Wave Field—R. Schüpbach and A. de Quervain. (*Brown Boveri Rev.*, vol. 31, pp. 292–295; September, 1944.) A general discussion of measurement techniques and screening, and a description of cavity-resonator couplings. Curves are given for a filter consisting of two inductively coupled resonators which are damped to give a Q of 350 and a coupling factor of 0.51 per cent.

621.396.611.21:529.786 3362
A Quartz Clock—Booth. (*See* 3388.)

621.396.611.21:621.396.615 3363
A 100 kc/s Quartz Frequency Sub-Standard and Harmonic Generator—E. W. Nield. (*R.S.G.B. Bull.*, vol. 22, pp. 39–40; September, 1946.) An inductance-capacitance circuit tuned to the resonant frequency of the crystal is placed in series with the latter; this arrangement effectively cancels stray reactances which might otherwise impair stability. A 50 per cent change of supply voltage produces a fundamental frequency change of only a fraction of a cycle per second.

621.397.79:621.396.621 3364
Tracer Plus Power Supply—W. H. Watkins. (*Radio Craft*, vol. 17, pp. 756–791; August, 1946.) Wiring diagram and constructional details of an equipment suitable for servicing tests at radio frequency, intermediate frequency and audio frequency on radio receivers and sound equipment.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

518.5:621.3 3365
Computation Problems in Circuit Design—G. T. Baker. (*P.O. Elec. Engrs. Jour.*, vol. 39, part 2, pp. 58–63; July, 1946.) The fundamental processes of computation,when numbers are expressed on the binary scale, may be represented physically by the action of a simple two-position relay. Circuits are given which perform these operations, with extension to the decimal scale. The technique is illustrated by an application to time-measurement problems.

621.317.083.7 3366
Telemetering Equipments for the Transmission of Any Desired Measurements Over Long Distances—Jaggi. (*See* 3343.)

621.317.39:537.221:544.8:669.018 3367
Sorting Alloys—N. F. Agnew. (*Electronics*, vol. 19, pp. 124–125; September, 1946.) Short description, with a circuit diagram, of a device for the nondestructive identification of alloys. A piece of standard metal is rubbed against the metal to be tested, and the resulting triboelectric voltage is measured. The instrument is calibrated by reference to materials of known composition.

621.317.39:620.172.222 3368
The Electrical Measurement of Strain—S. C. Redshaw. (*Jour. R. Aero. Soc.*, vol. 50, pp. 568–602; discussion, pp. 603–612; August, 1946.) Description of strain gauges in which mechanical strains produce variations in electrical parameters. Resistance-type gauges consisting of fine wire mounted on slips of paper cemented to specimens under test are found to be of most general use.

621.317.39:621.753.3 3369
Capacitive Micrometer—R. W. Dayton and G. M. Foley. (*Electronics*, vol. 19, pp. 106–111; September, 1946.) The principle used is that the change in capacitance between an electrode and the specimen examined is used to change the frequency of an oscillator, and hence, by means of a discriminator following a frequency converter and amplifier, to produce a proportional voltage for driving an indicator. Circuit diagrams of two such devices are given, and applications to the measurement of lathe-spindle movement and to dilatometers, manometers, roughness gauges, and hardness testers are described briefly. Design considerations and limits to the technique are discussed. Performance characteristics of typical instruments are given in tables. See also 2991 of October (Hayman), and 3370 below (Foley).

621.317.39:621.753.3:621.941 3370
Testing of Precision-Lathe Spindles—G. M. Foley. (*Trans. Amer. Soc. Mech. Eng.*, vol. 67, pp. 553–556; October, 1945.) An account of an application of the equipment described in 3369 above (Dayton and Foley).

621.317.39.083.+621.316.7]:[533.275+536.5 3371
Recorder-Controller for Temperature and Humidity—V. D. Hauck, R. E. Sturm, and R. B. Colt. (*Electronics*, vol. 19, pp. 96–99; September, 1946.) Temperature is indicated by a temperature-sensitive resistor, and humidity by means of a hair hygrometer that controls the position of a contact on a resistor. The recorder (of which a simplified circuit diagram is given) scans eight pairs of remote measuring units every fifteen minutes. The resistors in each unit control a recorder or humidity-control devices through a self-balancing bridge. A general technical description of the device is given.

621.317.39.087.4:533.275 3372
Humidity Recording—P. E. Maier. (*Elec. Ind.*, vol. 5, pp. 70, 102; July, 1946.) Description of an equipment for continuously recording the relative humidity of a gas. A dew-point mirror on a copper tube is observed with a photocell. When no dew is present, relays cause cooling water to flow in the tube and the flow stops when the dew forms. The temperature of the tube, therefore, hunts, with the dew point as maximum. The temperatures of the pipe and of the gas are measured with resistance thermometers that are connected in a circuit arranged to combine the readings to give the value of the relative humidity on a recording ohmmeter.

621.317.755:535.33:535.61–15 3373
"Instantaneous" Presentation of Infra-Red Spectra on a Cathode Ray Screen—E. F. Daily and G. B. B. M. Sutherland. (*Nature* (London), vol. 157, p. 547; April 27, 1946.) The radiation is interrupted at 15 to 20 cycles,

and falls on a thermistor bolometer after passing through the spectrometer. The output of the bolometer bridge is amplified, rectified, and applied to the Y plates. X-plate deflection is associated with the frequency scan. See also 3374 below (King, Temple and Thompson).

621.317.755:535.33:535.61-15 **3374**
Infra-Red Recording with the Cathode Ray Oscilloscope—J. King, R. B. Temple. and H. W. Thompson. (*Nature* (London), vol. 158, pp. 196–197; August 10, 1946.) Brief description of an equipment similar to that used in 3373 above (Daly and Sutherland).

621.365.5 **3375**
Medium Frequency Power in Industry—H. Fehlmann and V. Widmer. (*Brown Boveri Rev.*, vol. 31, pp. 159–162; May, 1944.) Brief account of the consideration of an induction furnace plant, with considerations on the design of unipolar generators, for operation in the range 250 to 10,000 cycles.

621.365.92 **3376**
Basic Factors in Dielecrtic Heating: Part 1—E. S. Winlund. (*Elec. World*, vol. 126, p. 80; August 3, 1946.) Formulas, with numerical examples relating minimum heating time, transfer efficiency, and required power, to the nature and thickness of the material to be heated and to generator frequency. First of three articles.

621.365.92 **3377**
Dielectric Heating—A. J. Maddock. (*Jour. Sci. Instr.*, vol. 23, pp. 165–173; August, 1946.) A general review of the subject, including an outline of the theory and an account of useful applications.

621.38:6 **3378**
Industrial Electronics—(*Engineer* (London), vol. 182, pp. 54–55; July 19, 1946.) Some examples of thyratron and ignitron control devices shown at the British Thomson-Houston symposium. Particular attention is paid to motor control, voltage regulation, and resistance welding. For another account see *Engineering* (London), vol. 162, p. 68; July 12, 1946.

621.383:621.316.578:628.971.6 **3379**
Photoelectric Street Lighting Control—C. E. Marshall. (*Electronics*, vol. 19, pp. 134–136; September, 1946.) Description, with circuit diagrams, of a device for switching the lights according to the local degree of darkness. Features such as proper selection of time delays and operating thresholds are discussed in some detail.

621.385.833+537.533.72 **3380**
The Variation of Resolution with Voltage in the Magnetic Electron Microscope—Cosslett. (*See* 3245.)

621.385.833+537.533.72 **3381**
A Study of Distortion in Electron Microscope Projection Lenses—J. Hillier. (*Jour. Appl. Phys.*, vol. 17, pp. 411–419; June, 1946.) "The origin of distortion . . . is discussed and the serious nature of its effect on the measurement of particle size distributions is pointed out. Methods of measuring distortion are described. By means of first-order theory it is shown to be possible to correct distortion by the use of a two-element projection lens. The degree of correction obtainable is shown to be satisfactory for most practical purposes. A double gap projection lens polepiece and the correction of distortion obtained with it are described."

621.385.833+537.533.72 **3382**
A Zonally Corrected Electron Lens—D. Gabor. (*Nature* (London), vol. 158, p. 198; August 10, 1946.) A new type of lens to reduce spherical aberration in an electron microscope, uses a central wire surrounded by several annular electrodes. It is unsuitable as a microscope objective, but may be used to correct objectives. This lens also reduces depth of focus and may be useful for exploring objects in depths.

621.385.833 **3383**
Some Recent Development in the Field of Electron Microscopy—R. W. G. Wyckoff. (*Science*, vol. 104, pp. 21–26; July 12, 1946.)An account of the present position and future possibilities of electron microscopy for the examination of tissues, surface structure, and organisms of interest in bacteriology.

621.385.833 **3384**
Electron Optics and Its Application to the Electron Microscope—P. Chanson. (*Onde Élect.*, vol. 26, pp. 95–100; March, 1946.) A description of the general theory, with particular reference to the wave interpretation of high-speed electrons. The author concludes with a short note on the present advanced state of development of this subject in France. In particular, work at the Collège de France is pointing the way to a "proton microscope," with the possibility of magnifications up to 400,000 (see 2659 of September—Magnan, Chanson and Ertaud).

621.385.833 **3385**
Contour Fringes and Asymmetries of Electron Microscope Objectives—J. Hillier and E. G. Ramberg. (*Phys. Rev.*, vol. 70, p. 113; July 1–15, 1946.) Abstract of an American Physical Society paper.

621.385.833 **3386**
Modifications of Specimens in Electron Microscopy—L. Marton, N. N. Das Gupta and C. Marton. (*Science*, vol. 104, pp. 35–36; July 12, 1946.) Stresses the necessity for obtaining independent evidence on the stability of specimens under examination.

621.385.833 **3387**
Frozen-Dried Preparations for the Electron Microscope—R. W. G. Wyckoff. (*Science*, vol. 104, pp. 36–37; July 12, 1946.) A method of preparation for obtaining specimens without distortion or shrinkage.

621.396.611.21:529.786 **3388**
A Quartz Clock—C. F. Booth. (*P. O. Elec. Eng. Jour.*, vol. 39, part 2, pp. 33–37; July, 1946.) A general description of the principles, with details of equipment being produced by the British Post Office for the Royal Observatory.

621.396.931 **3389**
New Radio Warning Device Tested by Chicago and North Western—(*Telegr. Teleph. Age*, vol. 64, pp. 26, 27; August, 1946.) Note on a new "slow-tone" device, for use on trains, which broadcasts a series of high-pitched notes at four-second intervals, allowing voice communication at the same time.

623.26:621.396.9 **3390**
How Mine Detectors Work—E. Leslie. (*Radio Craft*, vol. 17, pp. 676, 721; July, 1946.) General description, with circuit diagrams, of one audio-frequency mutual-inductance type for detecting metallic mines.

786.6:621.383 **3391**
Photoelectric Tone Generator—L. E. Greenlee. (*Electronics*, vol. 19, pp. 93–95; September, 1946.) An account of the device described in 2668 of September (Campbell and Greenlee).

PROPAGATION OF WAVES

523.78:[551.51.053.5+621.396.11 **3392**
The Solar Eclipse of 1945 and the Propagation of Radio Waves—R. L. Smith-Rose. (*Alta Frequenza*, vol. 15, pp. 37–38; March, 1946.) Long summary in Italian of 1831 of July.

537.56:621.396.11 **3393**
Conduction and Dispersion of Ionized Gases at High Frequencies—Margenau. (*See* 3246.)

621.396.11 **3394**
Study of the Propagation of Electromagnetic Waves in Mountains, Valleys, Fiords, etc.—B. Polié. (*Onde Élect.*, vol. 26, p. 7A; March, 1946.) Abstract of a paper appearing in *T.S.F. Technik*, vol. 33, April, 1944, and in *Jour. Télécomm.*, vol. 7, pp. 57–62; May, 1945.) Vilbig has suggested that a valley acts as a waveguide, only propagating waves below a critical wavelength. The author has tested the theory with sheet-iron models (scale about 1:500) at wavelengths 0.8 to 4 meters. There was a cutoff wavelength equal to twice the valley width except for polarization normal to the valley wall, when there was no cut off, but appreciable attenuation at all wavelengths.

621.396.11:551.51.053.5 **3395**
The Ionosphere and Short-Wave Broadcasting—T. W. Bennington. (*B.B.C. Quart.*, vol. 1, pp. 29–32; April, 1946.) An elementary survey.

621.396.11.029.6:546.21-1 **3396**
The Absorption of One-Half Centimeter Electromagnetic Waves in Oxygen—R. Beringer. (*Phys. Rev.*, vol. 70, pp. 53–57; July 1 and 15, 1946.) "The apparatus employs a [1-centimeter] klystron oscillator, crystal-rectifier frequency-multiplier, wave guide absorption, path, and crystal detector. The measured values [for oxygen and oxygen-nitrogen mixtures] are in agreement with the theory of Van Vleck [unpublished reports] both as regards the absolute value of the absorption . . . and the dependence on pressure." The sharp peak of the absorption curve occurs very close to 0.5 centimeters wavelength, and at the peak gives rise to attenuations (at normal pressure) of about 67 and 15 decibels per kilometer for pure oxygen and air respectively.

621.396.11.029.64:535.343.4 **3397**
Expected Absorption in the Microwave Region by Water Vapor and Similar Molecules—Hainer King and Cross. (*See* 3235.)

RECEPTION

621.396.619.018.41 **3398**
Frequency Modulation: Part 3—Courtillot. (*See* 3420.)

621.396.619.018.41 **3399**
The Mutual Effect of Two Frequency Modulated Waves in Limiters—P. Güttinger. (*Brown Boveri Rev.*, vol. 31, pp. 296–297; September, 1944.) The frequency spectrum is calculated. It is shown that the audio frequency of only one transmitter remains. The audio frequency of the other transmitter and overtones and beat notes of the audio frequencies are absent. The disturbing element consists chiefly of beat notes due to the difference between the carrier frequencies and their harmonics.

621.396.621+621.396.61 **3400**
Inside the Handie-Talkie—Scott. (*See* 3449.)

621.396.621 **3401**
Some Radio Receiver Design Considera-

tions—P. P. Di Roberto. (*Alta Frequenza*, vol. 14, pp. 232–234; September–December, 1945.) Long summary of a paper in *Boll. Inform. Comp. Gen. Elett.*, pp. 8–15; April, 1945.

621.396.621 3402
The Radio News Circuit Page—(*Radio News*, vol. 36, pp. 64, 71; August, 1946.) For previous parts see 2680 of September.

621.396.621 3403
Radio Data Sheet 337—(*Radio Craft*, vol. 17, p. 691; July, 1946.) Servicing data for Emerson Radio Models 501, 502, and 504.

621.396.621 3404
Radio Data Sheet No. 338—(*Radio Craft*, vol. 17, p. 762; August, 1946.) Servicing data for General Electric Model 250 receiver.

621.396.621+621.396.61].029.62 3405
Transmitter-Receiver for Ham Beginners: Part 1—C. M. Sullivan. (*Radio News*, vol. 36, pp. 32, 140; August, 1946.) A description of the design and construction of a superregenerative receiver for use in the 144- to 148-megacycle band. The audio-frequency section is used as the modulator of the transmitter.

621.396.621+621.396.61].029.63 3406
2,700 Mc/s Transceiver—K.H. (*See* 3488.)

621.396.621.029.64 3407
Low Noise Microwave Video Receiver Design—W. J. Zable. (*Radio*, vol. 30, pp. 10, 32; July, 1946.) New design factors for a low-noise input circuit comprising a neutralized triode followed by a grounded-grid output tube are discussed. The analysis of a κ network suitable for coupling to a crystal mixer is given.

621.396.621.54 3408
Practical Radio Course. Part 47—A. A. Ghirardi. (*Radio News*, vol. 36, pp. 46, 111; August, 1946.) An account of multigrid mixers and converters. For previous parts see 2684 and 2692 of September and back references.

621.396.622.4.029.64:537.228.4 3409
Optical Microwave Detector—P. H. Miller, Jr., and B. Goodman. (*Phys. Rev.*, vol. 70, p. 110; July 1–15, 1946.) A proposed device in which plane-polarized monochromatic light is modulated in passing through a Kerr cell in a resonant cavity and through an analyzer. The spacing of the sidebands so produced about the light frequency may be measured on an interferometer. The instrument is expected to have a sensitivity of 10^{-7} watts, but means of improving this to 10^{-12} watts are envisaged. Abstract of an American Physical Society paper.

621.396.645 3410
Design of Broad Band I.F. Amplifiers—*Baum.* (*See* 3223.)

621.396.822 3411
Statistical Analysis of Spontaneous Electrical Fluctuations—R. Fürth and D. K. C. MacDonald. (*Nature* (London), vol. 157, p. 807; June 15, 1946.) A recently developed statistical theory of electrical fluctuations such as shot effect has been found to give good agreement with experimental results.

621.397.62 3412
Television Receivers—Monfort. (*See* 3447.)

STATIONS AND COMMUNICATION SYSTEMS

621.396:061.5 3413
High-Frequency and Communications Engineering—(*Brown Boveri Rev.*, vol. 32, pp. 73–77; January–February, 1945.) A brief review of progress and work of the Brown Boveri Company in 1944 with special mention of stability tests on sets designed for aircraft communication purposes.

621.396.2 3414
Mobile Relay Broadcasting—H. E. Ennes. (*Radio*, vol. 30, pp. 17–19, 30; July, 1946.) A pack transmitter is used at the scene of the broadcast. The transmission is picked up by a mobile unit and relayed to the nearest point that is linked to the studio by audio wire line. Detailed descriptions of the various equipments are given.

621.396.43 3415
Various Possible Applications for Beam Transmission—R. Schüpbach. (*Brown Boveri Rev.*, vol. 31, pp. 288–291; September, 1944.) Graphs give the maximum elevation of the ground permissible for a communication link on 75-centimeter wavelength, and a radio-telephone link using frequency modulation is described.

621.396.44+621.392.2]:551.574.7 3416
The Effect of Sleet on the Propagation of Carrier Waves along High-Voltage Transmission Lines—A. Wertli. (*Brown Boveri Rev.*, vol. 31, pp. 362–366; November, 1944.) A short account of the experimental recording apparatus used on the Schwägalp-Säntis line together with photographs of the line and a typical record. No results are given.

621.396.44+621.398 3417
Carrier-Current Communication over High-Voltage Transmission Lines—E. Hancess. (*Brown Boveri Rev.*, vol. 31, pp. 335–339; October, 1944.) An outline of a system for a 10-kilovolt power line, with a description of the coupling units and protective devices, and a short consideration of the range and efficiency as limited by line noise and climatic conditions.

621.396.619.018.41 3418
Frequency Modulation—P. Besson. (*Onde Élect.*, vol. 26, pp. 239–256; June, 1946.) Conclusion of 2703 of September. See also 3419 and 3420 below (Matricon: Courtillot).

621.396.619.018.41 3419
Frequency Modulation: Parts 1 and 2—M. Matricon. (*Rev. Tech. Comp. Franç. Thomson-Houston*, pp. 5–43; January, 1944.) An elementary survey dealing with general principles and the methods of generation of frequency-modulation waves. For part 3 see 3420 below. See also 3418 above (Besson).

621.396.619.018.41 3420
Frequency Modulation: Part 3—E. P. Courtillot. (*Rev. Tech. Comp. Franç. Thomson-Houston*, pp. 3–24; October, 1945.) For parts 1 and 2 see 3419 above. This part deals with reception, including signal-to-noise ratio and distortion.

621.396.619.16 3421
Pulse Modulating System—W. R. Greer. (*Electronics*, vol. 19, pp. 126–131; September, 1946.) Description of equipment similar to that described in 2315 of August (Kelleher) and back references.

621.396.712 3422
Studio Equipment: a New Design—H. D. Ellis. (*B.B.C. Quart.*, vol. 1, pp. 21–28; April, 1946.)

621.396.712.004.5 3423
Preventive Maintenance for Broadcast Stations—C. H. Singer. (*Communications*, vol. 26, pp. 33, 54; August, 1946.) A discussion of the facilities required for routine upkeep work, with advice on safety precautions. Third of a series; for previous parts see 3055 of October and 2709 of September.

621.396.931.029.62 3424
A Method of Increasing the Range of V.H.F. Communication Systems by Multi-Carrier Amplitude Modulation—J. R. Brinkley. (*Jour. I.E.E.* (London), part I, vol. 93, pp. 360–362; August, 1946.) Summary of 2326 of August.

621.396.933 3425
Aviation Radio—G. Newstead. (*Proc. I.R.E.* (Australia), vol. 7, pp. 3–19; April, 1946.) A survey of the factors affecting the choice of frequency bands, the spacing of ground stations for communication purposes, navigation aids, and ground station design, with special reference to Australian conditions. Consideration is given to the effects at various frequencies of atmospherics, precipitation and man-made static, and of the ionosphere. Graphs show the variation of field strength with distance and flying height.

A description is given of the United States Civil Aeronautics Administration very-high-frequency (120 megacycles) radio range which provides course indication on a pointer-type instrument with aural quadrant indication by the A-N system.

Problems discussed include operation of transmitters and receivers on sites remote from the airport and reception in proximity to the transmitter.

621.397.7 3426
A Plan for Television Studios—P. Bax. (*B.B.C. Quart.*, vol. 1, pp. 47–51; July, 1946.) The present studio arrangement at Alexandra Palace has several serious disadvantages. Improvements in design for a future station are discussed whereby the studios and the associated departments are arranged to form a segment of a circle, thus giving facilities for any subsequent expansion.

SUBSIDIARY APPARATUS

531.787 3427
An Accurate Bellowa Manometer—H. G. East and H. Kuhn. (*Jour. Sci. Instr.*, vol. 23, p. 185; August, 1946.) Description of an instrument in which the expansion and contraction of bellows is transmitted to an optical lever. Pressure differences at any absolute value from vacuum up to several atmospheres may be measured with a sensitivity of 5×10^{-4} millimeters of mercury.

621.3.085.22 3428
Meter and Instrument Jewels and Pivots—G. F. Shotter. (*Jour. I.E.E.* (London), part I, vol. 93, pp. 276–278; June, 1946.) Long abstract of paper published in *Jour. I.E.E.* (London), part II, vol. 93, February, 1946. For another abstract see 2738 of 1945.

621.314.2:621.395:621.316.974 3429
The Magnetic Screening of Telephone Transformers—P. Nucci. (*Alta Frequenza*, vol. 14, pp. 11–80; March–June, 1945.) With English, French and German summaries.) Screening for static and for low-frequency fields is investigated theoretically for magnetic and nonmagnetic materials. The screening effect is substantially independent of the shape and in some cases of the absolute dimensions of the screen; it increases linearly with screen permeability and with its thickness when this is small, and it also increases exponentially with the number of screens. The screening is expressed in terms of p = geometrical thickness versus penetration depth. If $p\gg1$ the screening varies as e^p.

Experiments on single and multiple screens are described with particular reference to disturbing fields from main transformers. The screening effect follows the theoretical formulas qualitatively but is always smaller, probably due to uncertainty in the initial permeability and to decrease of the permeability with increasing frequency. The latter effect makes copper screens preferable above a certain frequency because of their higher conductivity.

Correction factors to the theoretical formula are given, enabling the attenuation of a screening system to be calculated with sufficient accuracy. The appendix contains a detailed mathematical treatment of screening applied to spherical, cylindrical, and multiple concentric screens.

621.314.2.029.5:621.396.621.54 3430
Two-Frequency I.F. Transformers—R. T. Thompson. (*Electronics*, vol. 19, pp. 142, 158; September, 1946.) Description of the construction and performance of transformers for use at 455 kilocycles and 8.3 megacycles.

621.314.5 3431
Modern Vibratory Power Converters—L. S. Distin. (*P. O. Elec. Eng. Jour.*, vol. 39, part 2, pp. 53–57; July, 1946.) The principles of operation of rectifying and nonrectifying types, with a description of a rectifier type specially developed for service use.

621.314.6 3432
A Note on Empirical Laws for Non-Linear Circuit Elements and Rectifiers—Corbyn. (*See* 3195.)

621.316.5 3433
Circuit Interruption—R. W. J. Cockram. (*Elec. Rev.* (London), vol. 139, pp. 385–388; September 6, 1946.) A brief history of circuit-breaking techniques and detailed descriptions of two modern developments: (a) the micro-break switch; and (b) a modified form of the conventional tilting mercury switch.

621.318.323.2.042.15 3434
Brown Boveri Powdered-Iron Cores for Filter and Tuned Coils in Communications Engineering—E. Ganz. (*Brown Boveri Rev.*, vol. 31, p. 331; September, 1944.) Figure-of-merit Q is graphed against frequency (0–16 kilocycles) for various permeabilities of an annular core, and for different numbers of turns.

621.318.323.2.042.15:621.396.662.2 3435
Coils with Iron Dust Cores—I. Avanessoff. (*Onde Élect.*, vol. 26, pp. 149–154; April, 1946.) An analysis of the losses associated with the cores, and a description of methods of measuring the components of these losses. It is shown that the performance of and the optimum frequency range for such coils can be calculated from a knowledge of the constructional details of the coil and the magnetic characteristics of the core. Experimental confirmation is given for a typical case.

621.319.51 3436
Electrode Evaporation and the Electric Spark—F. L. Jones. (*Nature* (London), vol. 157, pp. 298–299; March 9, 1946.) An equation is given which shows that for minimum erosion the electrodes should be composed of a material with the highest boiling point, density, and thermal conductivity. Good agreement with experimental data has been obtained in the case of airplane-engine spark plugs.

621.384 3437
The Racetrack: a Proposed Modification of the Synchrotron—H. R. Crane. **The Stability of Orbits in the Racetrack**—D. M. Dennison and T. H. Berlin. (*Phys. Rev.*, vol. 69, pp. 542 and 542–543; May 1–15, 1946.)

621.384 3438
Methods for Betatron or Synchrotron Beam Removal—E. C. Crittenden, Jr. and W. E. Parkins. (*Jour. Appl. Phys.*, vol. 17, pp. 444–447; June, 1946.) Two methods are discussed: one uses "a perturbing magnetic field to focus the electrons as they are made to leave the field of the accelerator by means of orbit expansion"; the other "makes use of a pulsed deflecting system where the deflecting field is applied during a time short compared to the period of revolution of the electrons."

621.384 3439
Removal of the Electron Beam from the Betatron—L. S. Skaggs, G. M. Almy, D. W. Kerst, and L. H. Lanzl. (*Phys. Rev.*, vol. 70, p. 95; July 1–15, 1946.)

621.384 3440
The Stability of Synchrotron Orbits—D. M. Donnison and T. H. Berlin. (*Phys. Rev.*, vol. 70, pp. 58–67; July 1–15, 1946.) Approximate solutions are obtained for the equations of motion of electrons in a synchrotron employing a frequency-modulated accelerating voltage. The electron orbits are shown to be stable. A numerical example is given.

621.396.66 3441
Broadcast Station Alarm System for Carrier and Program Failures—R. R. Taylor. (*Communications*, vol. 26, pp. 20, 55; August, 1946.) The circuit is given, and precautions to prevent actuation of the relays by momentary surges, etc., are detailed.

621.398:621.396.677 3442
A Simple Method of Controlling the Beam Antenna—Harris. (*See* 3191.)

TELEVISION AND PHOTOTELEGRAPHY

621.396.615.17:[621.317.755+621.397.331.2 3443
Current Oscillator for Television Sweep—Sziklai. (*See* 3220.)

621.397 3444
First Facsimile Newspaper Printed in Air Transport's Cabin—(*Telegr. Teleph. Age*, vol. 64, pp. 12, 14; August, 1946.) Brief description of equipment which gives a reception rate of 500 words per minute, and which can be adapted to transmit and receive flight and weather information from aircraft in flight.

621.397(73) 3445
Apparatus and Standards for Television Broadcasting in the U.S.A.—D. G. Fink. (*Alta Frequenza*, vol. 15, pp. 40–43; March, 1946.) Summarized excerpts in Italian from 3955 of 1945.

621.397.611:621.383.8 3446
Television Pickup Tubes—Blanc-Lapierre and Chantereau. (*See* 3472.)

621.397.62 3447
Television Receivers—R. A. Monfort. (*Radio News*, vol. 36, pp. 41–44, 150; August, 1946.) A discussion of some of the technical features, including aerial design, frequency-modulation sound channels, alignment of the video intermediate-frequency amplifier, the differentiating and integrating circuits in the synchronizing stages, and the use of test patterns.

621.397.813 3448
Theoretical Investigation of the Distortion of Television Signals in Valve Circuits—Huber. (*See* 3228.)

TRANSMISSION

621.396.61+621.396.621 3449
Inside the Handie-Talkie—R. F. Scott. (*Radio Craft*, vol 17, pp. 684, 724; July, 1946.) Description, with circuit diagrams, of the United States Army equipment SCR-536.

621.396.61 3450
Broadcast Transmitter Designs as Determined by a Market Survey—M. R. Briggs. (*Communications*, vol. 26, pp. 11–14, 44; August, 1946.) An account of a survey of opinions and preferences of 91 station managers and operators.

621.396.61 3451
Special Transmitters for Wireless Broadcasting, Telephony, and Telegraphy—M. Dick. (*Brown Boveri Rev.*, vol. 31, pp. 281–287; September, 1944.) Describes the mechanical layout, with the aid of photographs, of 10-kilowatt transportable medium- and short-wave transmitters.

621.396.61:621.396.619.018.41 3452
Direct F.M. Transmitters—N. Marchand. (*Communications*, vol. 26, pp. 24, 54; August, 1946.) A typical transmitter is described consisting of an exciter unit employing a reactance-tube-modulated oscillator, frequency-multiplying stages, and radio-frequency class-C amplifier stages. The oscillator frequency is automatically stabilized by a two-phase motor in conjunction with a crystal. Part 8 of a series; for previous parts see 3105 of October and back references.

621.396.61:621.396.99 3453
Transmitting Stations for Police Forces and Fire Brigades—H. Labhardt. (*Brown Boveri Rev.*, vol. 32, pp. 105–109; March, 1945.) A nontechnical description, with photographs, of the applications of short-wave and ultra-short-wave equipments.

621.396.61.029.56 3454
Flea Power Voice Transmitter—A. B. Kaufman. (*Radio News*, vol. 36, pp. 35, 142; August, 1946.) Design and construction of a crystal-controlled single-tube transmitter of small size for operation in the 3-megacycle region. A pentode is used with suppressor-grid voice modulation.

621.396.61.029.58 3455
The "Monobloc" Short-Wave 15-kW Broadcast Transmitters Type TH 1417—M. Guérineau. (*Rev. Tech. Compt. Franç. Thomson-Houston*, pp. 31–36; April, 1946.) Detailed description of the mechanical and electrical design of a transportable and easily erected transmitter. At 95 per cent modulation the harmonic distortion is less than 2 per cent for 50 to 3000 cycles and 3.5 per cent for 3000 to 5000 cycles. The noise modulation is 55 to 60 decibel below the level corresponding to 80 per cent modulation at 800 cycles. The transmitter can operate on the broadcasting bands of 16, 19, 25, 31, and 41 meters.

621.396.61+621.396.621].029.62 3456
Transmitter-Receiver for Ham Beginners: Part 1—Sullivan. (*See* 3405.)

621.396.61.029.62 3457
Crystal Controlled 2-Meter Transmitter—W. D. Speight. (*Radio News*, vol. 36, pp. 36, 117; August, 1946.) Design and constructional details. A 7.2-megacycle crystal is used with one quintupler and two doubler stages feeding the final amplifier.

621.396.61+621.396.621].029.63 3458
2700 Megacycle Transceiver—K. H. (*Electronics*, vol. 19, pp. 104–105; September, 1946.) A short technical description of a portable (56 pound in two packs) highly directional telephone equipment, including a circuit diagram and sectional drawing of the cavity resonator used with the GL-446 lighthouse tube. Reliable range 30 miles.

621.396.61.029.64 3459
430 Mc with a 6F4—I. Queen. (*Radio Craft*, vol. 17, pp. 687, 724; July, 1946.) Con-

structional details of a coaxial-cavity amateur transmitter.

621.396.611.21:621.396.615 3460

A 100 kc/s Quartz Frequency Sub-Standard and Harmonic Generator—Nield. (*See* 3363.)

621.396.619 3461

Modulation: Part 1—Physical Basis [of Amplitude and Phase Modulation]—O. Henkler and R. Otto. (*Arch. Tech. Messen*, pp. T97–98; September, 1940.)

621.396.619 3462

Class B Modulator Design—Grant. (*See* 3221.)

621.396.619.018.41 3463

Frequency Modulation: Parts 1 and 2—Matricon. (*See* 3419.)

621.396.645.3 3464

[Short Wave] Transmitter Output Stage—H. D. Hooton. (*Radio Craft*, vol. 17, pp. 755, 799; August, 1946.) Constructional details of a neutralized push-pull radio-frequency amplifier designed to work from an exciter delivering 30 to 100 watts.

VACUUM TUBES AND THERMIONICS

537.221 3465

Contact Potential Difference in Crystal Rectifiers—W. E. Meyerhof. (*Phys. Rev.*, vol. 70, p. 106; July 1–15, 1946.) The contact potential of (mainly) silicon-metal point contact rectifiers has been measured (a) by variation of direct-current contact resistance as a function of temperature, and (b) by the Kelvin method where the semiconductor and metal are not in contact. The poor correlation between the results from the two methods "is probably caused by layers on the semiconductor and metal which undergo changes in forming a contact." See also 1282 of May (Meyerhof and Miller). Abstract of an American Physical Society paper.

621.3.032.21:537.585 3466

Positive Ions from Thoriated Tungsten—G. A. Jarvis. (*Phys. Rev.*, vol. 70, p. 106; July 1–15, 1946.) The specimen is prepared by heating to above 2600 degrees Kelvin, so as to reduce the thorium dioxide. It is then found "that the temperature dependence of positive thorium ion emission is similar to that for positive ions from pure metals." Simultaneous measurements made with a magnetic analyzer on the emission of thorium and tungsten positive ions as a function of temperature yield approximate values for the work functions. The growth of the thorium layer on a filament at 2000 degrees Kelvin has been examined. Abstract of the American Physical Society paper.

621.3.032.216:537.533.8 3467

Secondary Electron Emission from Oxide-Coated Cathodes: Part 2—M. A. Pomerantz. (*Jour. Frank. Inst.*, vol. 242, pp. 41–61; July, 1946.) Conclusion of 3107 of October. The apparatus and results are described in detail.

It is found that above a critical temperature, near that at which thermionic emission became appreciable, there was a time lag in the decay of the secondary emission after stopping the primary radiation. This is shown to be due to space-charge phenomena (see also 1482 of 1945—Johnson). The average energy of secondary electrons decreases as the target temperature is increased, so that the total energy of secondary emission remains roughly constant or tends to decrease although the total emission current rises. A qualitative explanation is suggested.

621.3.032.216:537.533.8 3468

The Temperature Dependence of Secondary Electron Emission from Oxide-Coated Cathodes—M. A. Pomerantz. (*Phys. Rev.*, vol. 70, pp. 33–40; July 1–15, 1946.) "Experiments have been performed with three types of apparatus [see 3467 above]. Yield versus energy data reveal values of δ of 4 to 7 at room temperature with a more or less flat maximum at approximately 1000 volts primary energy." Extrapolation of data suggests yields exceeding 100 at 850 degrees centigrade, but the product of yield and average energy per secondary decreases with increase in temperature. The temperature dependence of the yield is discussed but no satisfactory explanation is found. Yields under pulsed and steady state conditions are in agreement and the secondary emission, except in the presence of certain space charge effects, follows the primary waveform.

621.314.632:546.289 3469

The Photo-Diode and Photo-Peak Characteristics in Germanium—Benzer. (*See* 3314.)

621.319.7:621.385 3470

Potentiograms and Electron Trajectories in Electrostatic Fields—Pinciroli and Panetti. (*See* 3322.)

621.383.8:535.61-15 3471

Infrared Image Tube—G. A. Morton and L. E. Flory. (*Electronics*, vol. 19, pp. 112–114; September, 1946.) A description of the RCA 1P25 image converter. Electrons emitted by a photoelectric screen (cathode) sensitive to infra-red light are focused by an electron-lens on to a fluorescent screen of synthetic willemite. The cathode is made by depositing a base layer of silver on the glass of the tube, the layer is "completely oxidized and processed with additional silver, caesium and silver, with an appropriate thermal treatment." Application to various types of infra-red telescope is mentioned. See also 2661 of September and 2346 of August.

621.383.8:621.397.611 3472

Television Pickup Tubes—A. Blanc-Lapierre and J. Chantereau. (*Rev. Tech. Compt. Franç. Tgomson-Houston*, pp. 25–44; October, 1945.) Description of the principles of operation, construction, and characteristics of the emitron and superemitron types of camera. The paper concludes with a brief discussion of the advantages of "slow electron" tubes in which the collector anode is at zero potential.

621.385 3473

Demonstration of a Water-Jet Analogue of the Reflection Klystron—W. J. Scott. (*Proc. Phys. Soc.*, vol. 58, pp. 475–476; July 1, 1946.) The behavior of the electron beam in the electric field is simulated by a water jet under the influence of the gravitational field. The "bunching" action, as represented by the distribution of water globules, is clearly shown by stroboscopic photographs.

621.385 3474

The Construction and Operation of Klystrons—E. D. Hart. (*R.S.G.B.Bull.*, vol. 22, pp. 34–38; September, 1946.) Practical operating adjustments are described in some detail.

621.385 3475

Errata: On the Possibility of Purely Electrostatic Focusing in a Velocity Modulation Drift Tube—P. Guénard. (*Ann. Radioélect.*, vol. 1, p. 276; January, 1946.) Corrections to 3878 of 1945.

621.385.1 3476

Some Facts Concerning the Construction of Brown Boveri Small Tubes—A. Bertschinger. (*Brown Boveri Rev.*, vol. 31, pp. 313–315; September, 1944.) A general description.

621.385.16 3477

Space Charge in Plane Magnetron—L. Page and N. I. Adams, Jr. (*Phys. Rev.*, vol. 69, pp. 492–494; May 1–15, 1946.) "The space charge equation for the plane magnetron is solved, the current is obtained as a function of the magnetic field, and the effect of the magnetic field on the distribution of potential and charge is discussed."

621.385.16 3478

Space Charge in Cylindrical Magnetron—L. Page and N. I. Adams, Jr. (*Phys. Rev.*, vol. 69, pp. 494–500; May 1–15, 1946.) The space charge equation is solved for a system of two coaxial cylindrical electrodes, with a uniform axial magnetic field. Three forms of solution are obtained: (1) applicable near the inner electrode (cathode) for weak magnetic fields; (2) applicable at large distances from the cathode; and (3) applicable near cut-off. Curves illustrating the results are given.

621.385.16.029.62/.63 3479

Split Anode Magnetrons for the 100–800 Megacycle Range—J. P. Blewett, D. A. Wibur, and L. D. Roberts. (*Phys. Rev.*, vol. 70, p. 118; July 1–15, 1946.) Cathode back heating, anode dissipation at high frequencies, and escape of electrons from the anode structure at low frequencies limit the power output. A shielding process permits operation of small glass-enclosed magnetrons at powers greater than 1 kilowatt from 100 to 400 megacycles. Liquid cooling is used. Powers of 150 watts from 350 to 800 megacycles are obtained by mounting an internal loop in parallel with the external tank circuit. Abstract of an American Physical Society paper.

621.385.16.029.63 3480

Methods of Tuning Multiple-Cavity Magnetrons—R. B. Nelson. (*Phys. Rev.*, vol. 70, p. 118; July 1–15, 1946.) The most successful of several methods tried involves simultaneous variation of inductance and capacitance of all cavities by a single tuning motion. Tuning ranges greater than 1.4 to 1 have been obtained with good efficiency throughout; for example, a magnetron tuning from 760 to 1160 megacycles delivering over 2 kilowatts continuous-wave operation at all frequencies is described. Abstract of an American Physical Society paper.

621.385.3 3481

Sealed-Off Transmitting Tubes and Their Production—F. Jenny. (*Brown Boveri Rev.*, vol. 31, pp. 309–312; September, 1944.) A general description of the materials used and the methods of assembly, with characteristic curves for a 5-kilowatt air-cooled triode.

621.385.3 3482

New Manufacturing Techniques for Transmitter Tubes—M. Matricon and J. Chantereau. **The Standardization of the Components in the Manufacture of C.F.T.H. Transmitting Tubes**—R. Montagne. **Test Equipment for Materials in the Manufacture of Electronic Tubes**—A. Laurent. **Continuously Evacuated Demountable Transmitting Tubes**—M. Matricon. (*Rev. Tech. Comp. Franç. Thomson-Houston*, pp. 5–17, 19–22, 23–32, and 33–39; April, 1945.) Another account of the same material by the same authors is given in 490 of February and 1110 of April.

621.385.832 3483

The Image Formation in Cathode-Ray Tubes and the Relation of Fluorescent Spot Size and Final Anode Voltage—G. Liebmann: H. Moss. (PROC I.R.E. AND WAVES AND ELECTRONS, vol. 34, pp. 580–586; August, 1946.) Long discussion of 3030 of 1945 (Liebmann).

621.396.694 3484

The Calculation of Amplifier Valve Characteristics—G. Liebmann. (*Jour. I.E.E.* (London), part I, vol. 93, pp. 357–358; August, 1946.) Long summary of 2406 of August.

621.396.822+537.525.5]:621.385 3485
Noise and Oscillations in Hot-Cathode Arcs—Cobine and Gallagher. (*See* 3266.)

621.396.822+537.525.5]:621.385 3486
Effect of Magnetic Field on Noise and Oscillations in Hot-Cathode Arcs—Gallagher and Cobine. (*See* 3267.)

621.396.822:621.385[.12+.18 3487
A High Level Electronic Noise Source—J. D. Cobine and C. J. Gallagher. (*Phys. Rev.*, vol. 70, p. 119; July 1–15, 1946.) Continuous spectrum from low audio frequencies to above 5 megacycles built in form of a gas discharge tube with cylindrical electrode structure. The root-mean-square voltage is substantially flat up to 1 megacycle and drops 18 decibels from 1 to 5 megacycles. Abstract of an American Physical Society paper.

MISCELLANEOUS

027:[5+6 3488
Science Librarianship—J. W. Hunt. (*Science*, vol. 104, pp. 171–173; August 23, 1946.)

058:[621.38+621.396 3489
Electronics Buyers' Guide—The issue of June 15, 1946 contains (in addition to data on sources of supply) charts and tabulated information on the electromagnetic spectrum, frequency allocations, sound levels, graphical symbols, and solid-dielectric coaxial cables, and also an index to *Electronics* for 1936 to June 1946, and a bibliography of about 500 books on electronic and allied subjects.

347.771 3490
Patent Law Reform in Britain—(*Nature* (London), vol. 158, pp. 1–3; July 6, 1946.) Editorial on second interim report of the departmental committee on the Patent and Design Acts, dealing with the alleged abuse of monopoly rights, the grant of worthless patents, and the legal procedure for the determination of patent rights.

518.3 3491
Alignment Chart Construction—D. C. French. (*Proc. I.R.E.* (Australia), vol. 7, pp. 11–20; June, 1946.) A nontheoretical explanation.

519.283:519.24 3492
A Simple Test of Significance—E. J. Williams, K. K. Schiller. (*Engineering* (London), vol. 161, pp. 496 and 568; May 24, and June 14, 1946.) Two letters discussing the test proposed by "A. Mateur" (2427 of August).

621.3+537+538].081 3493
Electrical Units and the MKS System—H. P. Williams. (*Elect. Comm.*, vol. 23, pp. 96–106; March, 1946.) An instructional review.

621.3 3494
I.R.E.-U.R.S.I. Convene—(*Elec. Ind.*, vol. 5, pp. 75–77, 96; July, 1946.) Summaries of some of the papers read at the joint meeting held in Washington, D.C., in May, 1946.

621.3 3495
Electrical Progress and Development—H. W. Richardson. (*Gen. Elec. Co. Jour.*, vol. 14, pp. 3–56; February, 1946.) Survey of work at British General Electric Co., including radio and communications, measuring instruments and batteries.

621.3(07) 3496
A Note on Electrical Engineers Trained [in United States schools] During the War—G. H. Fett. (Proc. I.R.E. and Waves and Electrons, vol. 34, pp. 481–482; July, 1946.)

621.3.027.3:016.5 3497
High-Voltage Engineering—(*Brown Boveri Rev.*, vol. 30, pp. 211–291; September-October, 1943.) This is a special high-voltage engineering number of the journal, giving 16 papers on the properties of insulators, breakdown phenomena, and high voltage laboratory equipment.

621.3.078:621.383 3498
Step-Control of a Productive Process—W. Sommer. (*Jour. Sci. Instr.*, vol. 23, pp. 150–154; July, 1946.) Photoelectric device employing a series of filters of varying density for controlling tolerances in mass production processes.

621.3.084(07) 3499
Education in Instrument Technology. Report of a Discussion held by the Society of Instrument Technology in London on 8 November 1945—(*Jour. Sci. Instr.*, vol. 23, pp. 161–163; July, 1946.)

621.38 3500
Electronics Exhibition—(*Elect. Rev.* (London), vol. 139, pp. 93–94; July 19, 1946.) A review of the electronic equipment for controlling industrial processes, high-frequency heating, etc., shown at the British Thomson-Houston Co. exhibition. For another account see *Electrician*, vol. 137, pp. 165–167; July 19, 1946.

621.385 3501
Demonstration of a Water-Jet Analogue of the Reflection Klystron—Scott. (*See* 3473.)

621.396.6(213) 3502
Deterioration of Radio Equipment in Damp Tropical Climates and Some Measures of Prevention—C. P, Healy. (*Jour. I.E.E.* (Australia), vol. 18, pp. 73–85; April-May, 1946.) The nature of moulds, their reproduction, and the preparation of cultures are described. Moulds will grow on almost any organic material, and even in the surface of many inert materials if there is enough organic dust to maintain growth. In such cases the surface may be pitted. A survey of tropical conditions leads to the design of a humidity chamber in which tropical conditions may be simulated. Methods of inoculation of the equipment with mixed mould spores are described. Tests may also be carried out in petri dishes on small specimens and with particular moulds. The effectiveness of various fungicides, when incorporated in waxes, paints, etc., is discussed. The effects of mould on particular parts of equipment (connecting wire, laminated sheet, batteries, etc.) are considered, and methods of prevention or suitable substitutes recommended.

Humidity tests without moulds are outlined, and the effect on individual components considered. Preventive treatments are suggested for transformers, capacitors (paper and mica), ceramics, phenolic mouldings, and sheets. The use of moisture-proof equipment cases is mentioned. See also 809 of March (Collins, Gittoes, and Rowed).

621.396.621.004.67 3503
Hospitalization for Radios—O. I. Sprungman. (*Radio News*, vol. 36, pp. 45, 151; August, 1946.) Details of a type of insurance under which a yearly premium is paid and servicing is free for the year.

621.396.97:7 3504
The Search for a Radiophonic Art—J. Matras. (*Onde Élect.*, vol. 26, pp. 228–238; June, 1946.) An essay on the aesthetics of broadcasting as a cultural medium, by the chief engineer of the French broadcasting system.

658.311.5 3505
The Selection of Engineering Personnel—F. Holliday. (*Jour. Aero. Soc.*, vol. 50, pp. 240–261, discussion, pp. 262–274; April, 1946.) A lecture before the Royal Aeronautical Society.

778.142 3506
Microfilm—M. Sollima. (*Rev. Tech. Compt. Franç., Thomson-Houston*, pp. 1–20; July, 1945.) A general account, with particular note of cameras and reading apparatus developed by the French Thomson-Houston Company.

519.283:62 3507
A First Guide to Quality Control for Engineers. [Book Review]—E. H. Sealy. H.M. Stationery Office, London, 1945, 38 pp., 1s. (*Nature* (London), vol. 157, pp. 475–476; April 13, 1946.) A guide to production engineers in the application of statistical methods of checking and testing in mass production.

551.5(021) 3508
General Meteorology. [Book Review]—H. R. Byers. McGraw-Hill Book Co., New York, 1944, 645 pp., $5.00. (*Jour. Appl. Phys.*, vol. 17, p. 535; June, 1946.) ". . . recommended to persons interested in modern developments in descriptive and synoptic meteorology."

Correction.—In the October abstracts, for *Physica, Eindhoven* read *Physica, 's Grav.*

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(Including WAVES AND ELECTRONS Section)

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Index to Volume 34—1946

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NOTE

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In addition to the material published in the PROCEEDINGS, Standards on various subjects have been printed. These are available at the prices listed below.

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1) **Standards on Electroacoustics, 1938 Definitions of Terms, Letter and Graphical Symbols, Methods of Testing Loud Speakers.** (vi+37 pages, 6×9 inches)	$0.50
2a) **Standards on Electronics: Definitions of Terms, Symbols, 1938.** A Reprint (1943) of the like-named section of "Standards on Electronics, 1938." (viii+8 pages, 8½ x 11 inches)	$0.20
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5b) **Standards on Radio Wave Propagation: Measuring Methods, 1942.** Methods of Measuring Radio Field Intensity, Methods of Measuring Power Radiated from an Antenna, Methods of Measuring Noise Field Intensity. (vi+16 pages, 8½ x 11 inches)	$0.50
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Normas Sobre Receptors de Radio, 1938.* A Spanish-language translation of "Standards on Radio Receivers, 1938," by the Buenos Aires Section of the Institute of Radio Engineers. (vii+64 pages, 6 x 9 inches)	Two Argentine Pesos (Postpaid)

* *Not carried in stock at I.R.E. Headquarters in New York. Obtainable only from Señor Domingo Arbó, Editor of Revista Telegrafica, Peru, 165, Buenos Aires, Argentina.*

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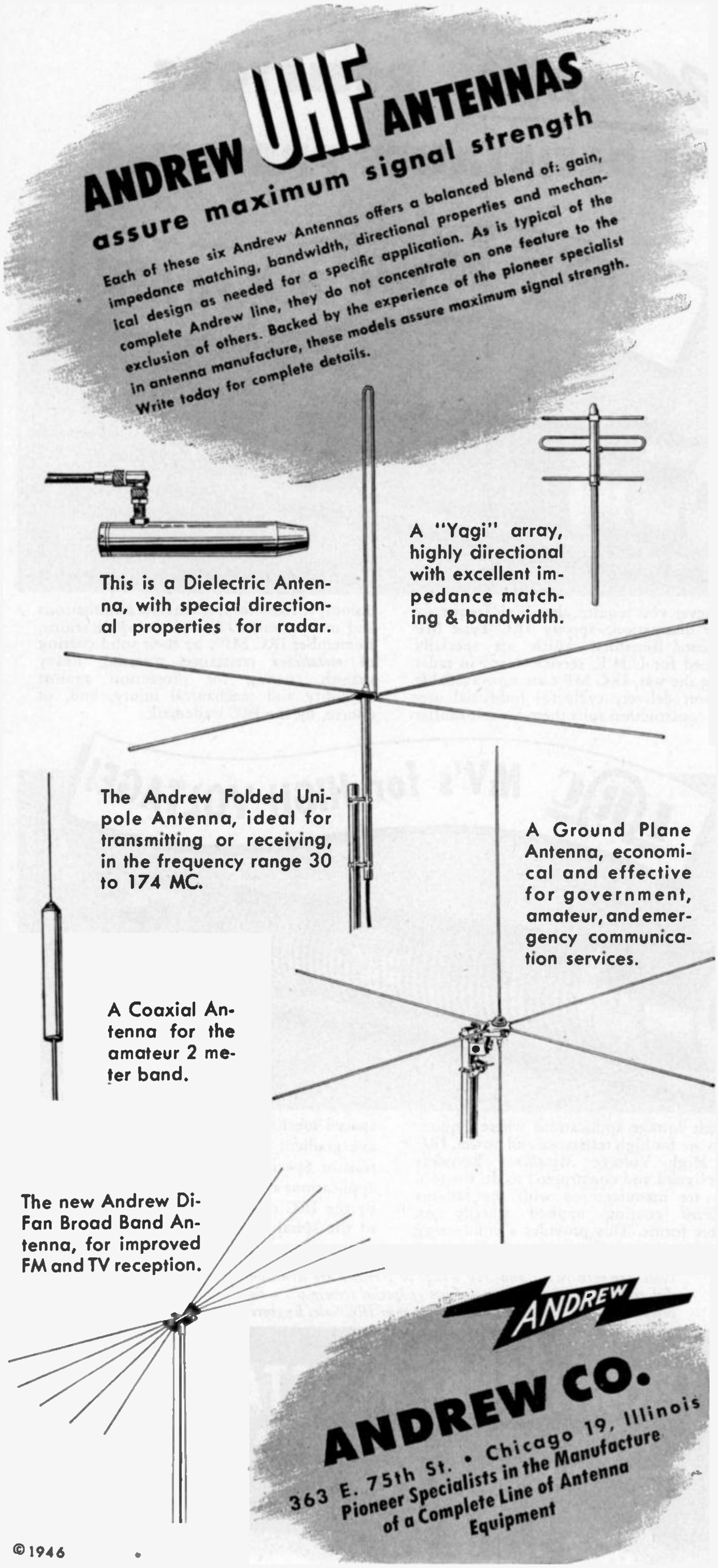

Atlanta

"Charting the Course of the Institute of Radio Engineers," by F. B. Llewellyn, President of the Institute of Radio Engineers, Inc.; September 27, 1946.

Baltimore

"Transmission Lines for Radio Frequencies," by C. R. Cox, Andrew Company; September 24, 1946.

Boston

"Electronics at Bikini," by D. G. Fink, Executive Editor of *Electronics;* October 24, 1946.

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"Noise Levels," by F. Malvarez; July 12, 1946.

"Iron Cored Reactors with Direct Current," by R. McLoughlin; July 26, 1946.

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"Ultra-High- and Very-High-Frequency Antenna Systems," by A. G. Kandoian, Federal Telecommunication Laboratories; October 16, 1946.

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"The Phasitron Frequency-Modulation Tube," by L. Findley, Collins Radio Company; October 16, 1946.

"Permeability Tuning," by F. N. Jacob, Aladdin Radio Industries; October 16, 1946.

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"Radar and Microwaves," by J. O. Perrine, Bell Telephone Laboratories; October 4, 1946.

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"The Panalyzer as an Engineering Tool," by J. Heller, Panoramic Radio Corporation; October 18, 1946.

Cincinnati

"Duo-Inductor," by John Reinartz, Radio Corporation of America; October 12, 1946.

"Comparative Performance of Frequency Modulation and Amplitude Modulation," by Sarkis Tarzian; October 15, 1946.

"Description of Converter, Receiver, and Transmitter," by Mr. Valdettaro and Mr. Weigel; October 15, 1946.

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"Staff Organization at I.R.E. Headquarters," by R. B. Jaques, Ohio State University; October 4, 1946.

"Human Engineering," by Melvin Evans; October 25, 1946.

"Ancient Musical Instruments," by M. E. Wilson, Ohio State University; October 25 1946.

Connecticut Valley

"Reflex Oscillators," by J. C. McNally, Bell Telephone Laboratories; September 26, 1946.

Dallas-Ft. Worth

"Design Considerations for Precision Master Oscillators," by T. A. Hunter, Collins Radio Company; October 8, 1946.

Dayton

"Adventures in Research," by Phillips Thomas, Westinghouse Electric Corporation; September 26, 1946.

Inspection Trip of Ohio Bell Telephone Company; October 10, 1946.

Detroit

"Modern Developments in Wire Recorders," by Mort Neff, WiRecorder Corporation; October 18, 1946.

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SECTION MEETINGS

(Continued from page 34A)

Houston

"The Design of Oscillators," by T. A. Hunter, Collins Radio Company; October 11, 1946.

London

Trip to Royal Canadian Air Force Radar and Communications School at Clinton, Ontario; October 15, 1946.

"Radar Antennas," by G. A. Miller, National Research Council; November 1, 1946.

Los Angeles

Charting the Course of the I.R.E.," by F. B. Llewellyn, President, The Institute of Radio Engineers, Inc.; September 12, 1946.

"Waves and Wavelets," by August Hund; October 20, 1946.

"The Behaviour of Dielectrics Over Wide Ranges of Frequency, Temperature, and Humidity," by R. F. Field, General Radio Company; October 20, 1946.

"High Frequency Circuits," by R. F. Walz, Air Associates, Inc.; October 20, 1946.

"Electronic Warfare," by F. E. Terman, Stanford University; October 20, 1946.

Milwaukee

"Research and Thinking," by J. W. Lawrie, Schlitz; September 12, 1946.

Montreal

"Radar Antennas," by G. A. Miller, National Research Council; October 9, 1946.

New York

"Magnetic Deflection of Kinescopes," by Kurt Schlesinger, Columbia Broadcasting System; October 2, 1946.

"Pulse-Type High-Voltage Supplies for Television Cathode-Ray Tubes," by J. R. Banker, Allen B. DuMont Laboratories; October 2, 1946.

North Carolina-Virginia

"Welcome to I.R.E.," by G. W. Bailey, Executive Secretary, Institute of Radio Engineers, Inc.; October 11, 1946.

"The Phasitron," by R. P. Watson, General Electric Company; October 11, 1946.

Ottawa

"A Very-High-Frequency Buoy Automatic Weather Station," by W. E. K. Middleton, National Research Council; October 8, 1946.

"A Very-High-Frequency Buoy Automatic Weather Station," by L. E. Coffey, Department of Transport; October 8, 1946.

"C.B.C. Operations," by N. R. Olding, Canadian Broadcasting Corporation; October 29, 1946.

Philadelphia

"New Television Field Pickup Equipment Employing the Image Orthicon, (Design Considerations)," by J. H. Roe, Radio Corporation of America; October 3, 1946.

"New Television Field Pickup Equipment Employing the Image Orthicon (Operations)" by E. C. Wilbur, National Broadcasting Company; October 3, 1946.

Pittsburgh

"Radio-Frequency Spectrum Analysis," by W. E. Good, Westinghouse Research Laboratory; September 9, 1946.

St. Louis

"Lighthouse and Phasitron Tubes," by R. P. Watson, General Electric Company; October 17, 1946.

(Continued on page 38A)

SECTION MEETINGS

(Continued from page 36A)

SAN DIEGO

"Charting the Course of the I.R.E.," by F. B Llewellyn, President, The Institute of Radio Engineers, Inc.; September 10, 1946.

TORONTO

"Television," by K. R. Patrick, RCA Victor Corporation; October 7, 1946.

WILLIAMSPORT

"Cathode-Ray Tubes—Design and Development," by W. A. Dickinson, Sylvania Electric Products, Inc.; October 9, 1946.

SUBSECTIONS

MONMOUTH

"Testing Repeaters with Recirculated Pulses," by A. C. Beck and D. R. Ring, Bell Telephone Laboratories; September 18, 1946.

"Radar Echoes from the Near-by Atmosphere," by M. W. Baldwin, Bell Telephone Laboratories; September 18, 1946.

PRINCETON

Symposium on Amplitude Ignoring Frequency-Modulation Detectors:

"General Survey," by M. G. Crosby, Paul Godley Consulting Engineers; October 9, 1946.

"The Ratio Detector," by S. W. Seeley, RCA Industry Service Laboratory; October 9, 1946.

"Single Stage Frequency-Modulation Detector," by W. E. Bradley, Philco Corporation; October 9, 1946.

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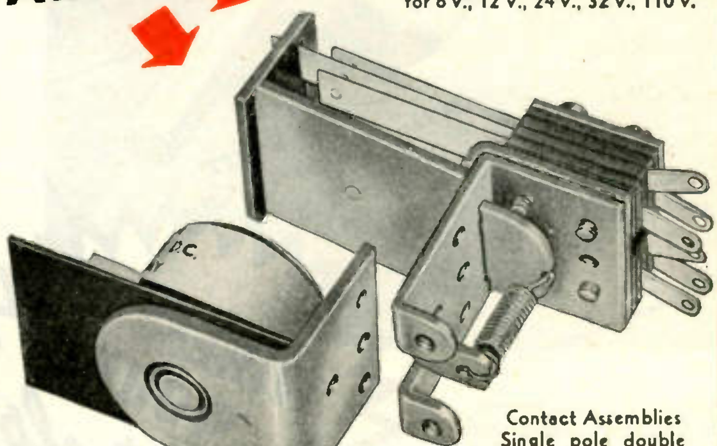

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9. **DUAL POWER SUPPLY** provides standby circuit instantly available for emergency use.
10. **POWER SUPPLY** designed for mounting on desk, wall or relay rack.
11. **INSTANT ACCESS** to all wiring and components. Top hinged panel opens at a touch. Entire cabinet tilts back on sturdy full-length rear hinge.

Raytheon's

RC-11 STUDIO CONSOLE

for AM or FM

The Most Versatile Unit of its Kind...Easily Controlling Two Studios, Announcer's Booth and Nine Remote and Two Network Lines.

FIRST UNVEILED at the I.R.E. Show last winter, this remarkable Raytheon Console has won a unique place in its field—commanding the attention of studio engineers and managers as few items of broadcast equipment ever have!

It provides *complete* high-fidelity speech-input facilities for the modern station—with all the control, amplifying and monitoring equipment contained in a single compact cabinet. It easily handles any combination of studios, remote lines or turntables—broadcasting and auditioning simultaneously, if desired, through two high quality main amplifier channels. It makes it a simple matter to cue an oncoming program and pre-set the volume while another program is on the air.

Note the sloping front and backward-sloping top panel, giving maximum visibility of controls and an unobstructed view into the studio. Note the telephone-type, lever action, three-position key switches, *eliminating nineteen controls* and reducing operational errors to a minimum.

The beauty of this console, in two-tone metallic tan . . . the efficient, functional look of it . . . will step up the appearance of any studio, and yet blend easily with other equipment. And the low price of this Raytheon Console will amaze you.

Inquire at once! Write or wire to:

RAYTHEON MANUFACTURING COMPANY

Broadcast Equipment Division **7517 N. Clark Street, Chicago 26, Ill.**

RAYTHEON

Devoted to Research and Manufacture for the Broadcasting Industry

Excellence in Electronics

MEMBERSHIP

(Continued from page 44A)

Johnson, G. L., Jr., 4701 W. Fulton St., Chicago 44, Ill.
Keyser, J. R., Jr., 1601½ Bedford Ave., Lynchburg, Va.
King, H. E., 905 Cooper St., Camden, N. J.
Kohut, M., 1205 Washington St., Farrell, Pa.
Kotadia, K. M., P. O. Himatnagar, (Gujarat) Idar State, India
Krcik, J. F., 36-63—34 St., Long Island City 1, N. Y.
Larrea, J. R., 916 Martin Garcia, Buenos Aires, Argentina
Leifer, M., Sylvania Electric Pruducts Inc., 34—10 Linden Place, Flushing, L. I., N. Y.
Lewis, E. W., 41 Regent Rd., Malden, Mass.
Lindner, F. A., c/o R.O.U., 1440 Broadway, New York, N. Y.
Lowery, H. R., 401 Franklin Ave., Valparaiso, Ind.
Manahan, M. J., 4461 W. 61 St., Los Angeles 43, Calif.
Mainieri, A. J., 25 de Mayo 360, San Isidro (Pcia de Buenos Aires), Argentina
Mansion, D. D., Ave. Huergo 1167, Buenos Aires, Argentina
Martin, R. E., 621 W. 172 St., New York 32, N. Y.
Meehan, J. D., 539 W. Fulton St., Long Beach, N. Y.
Mercader, R. L., 358—50 St., La Plata, Argentina
Meyer, H., 345 W. 70 St., New York 23, N. Y.
Mitchell, T. G., Thorn Acres, R.F.D. #4, Niles, Mich.
Mullenger, K. E., 17 Front St., Schenectady, N. Y.
Natrajan, R., Y.M.C.A., 215 W. 23 St., New York 11, N. Y.
Nelkin, A., 5447 Avondale Place, Pittsburgh, Pa.
O'Connor, D. G., 6823 Ridge Blvd., Brooklyn 20, N. Y.
Ohlinger, P. M., Portsmouth, Iowa
Onativia, R. A., Cia Standard Electric, Ave. Tomkinson 1700, San Isidro, F.C.C.A. Pcia Buenos Aires, Argentina
Osborn, W. C., Box 771, Dixon, Calif.
Parchment, E. D., c/o London Gramaphone Corp., 16–18 W. 22 St., New York, N. Y.
Patel, R. V., c/o RCA Institutes, 75 Varick St., New York, N. Y.
Patton, W. L., 5225 Wilshire Blvd., Los Angeles 36, Calif.
Peetz, G. E., Jr., 127 Orris St., Munhall, Pa.
Pendrill, E. M., 29A Epsom Rd., Morden, Surrey, England
Poritzky, S. B., 5210 Garfield, Kansas City 4, Mo.
Ravenscroft, H. A., 143 Howard St., Petaluma, Calif.
Reed, H. Z., 9 Sycamore Ave., Takoma Park 12, Md.
Ritz, W. A., 3505—37 St., Mount Rainier, Md.
Rockwell, W. S., c/o Graybar Electric Co., 1010 Rockwell Ave., Cleveland 14, Ohio
Rodriguez, F. V., Box 15, Hato Rey, Puerto Rico
Rose, F. H., c/o Allis-Chalmers Manufacturing Co., 650 Harrison St., San Francisco 7, Calif.
Rosenberger, T. A., 506 Delannoy Ave., Cocoa, Fla.
Sammon, A. C., 144 E. 40 St., New York 16, N. Y.
Santerre, R. E., 208 Bank St., Elkhart, Ind.
Savalli, F. P., 150 Wilson Ave., Brooklyn 21, N. Y.
Seidman, G., 4 S. Pinehurst Ave., New York 33, N. Y.
Shaffer, C. V., Box 432, Gainesville, Fla.
Shamblin, H. D., 3859 Kumquat Ave., Miami 33, Fla.
Sherline, M. J., 130 W. 64 St., New York 23, N. Y.
Silver, M. H., Box 847, Eau Gallie, Fla.
Smeltzer, J. C., R.F.D. #1, Box 156, Clinton, Md.
Sosolik, F. J., 1111 E. 23 St., Bryan, Texas
Soteriou, C. J., 143 Rea Ave., Hawthorne, N. J.
Spool, S., 116—65 Farmers Blvd., St. Albans 12, N. Y.
Stephens, G. F., 27 Monroe Place, Brooklyn 2, N. Y.
Stewart, F. L., 4215 16 St., N.W., Washington 11, D. C.

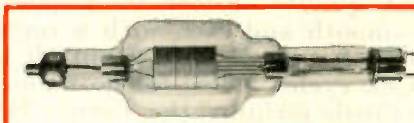
(Continued on page 48A)

BACK OF THIS LINE OF RECTIFIER TUBES . . .
50 YEARS OF HIGH-VOLTAGE EXPERIENCE

LOW internal drop, long filament life, and rugged mechanical construction characterize the Machlett line of high-voltage rectifier tubes. Machlett has devoted half a century to the design and manufacture of high-voltage electron tubes, and this long experience is reflected in today's Machlett rectifiers. Thus they incorporate such other assurances of long useful life as complete outgassing, ability to withstand high electrostatic stresses, and high plate dissipation to minimize the danger of back or secondary emission. In all Machlett tubes the glass envelopes are specially processed and minutely inspected to eliminate conditions that might lead to punctures.

For whatever purpose required—electrostatic precipitation, paint spraying, detearing, high-voltage testing of dielectrics and cables, or for research work requiring a reliable source of high-voltage D-C, there is a Machlett High-Voltage Rectifier designed and built to assure long, reliable performance.

Machlett Rectifiers are available up to 200 kv inverse, and in addition to a complete line of air-cooled tubes, there are types for oil-immersion designed for use in modern shockproof housings. The Machlett catalog, containing detailed descriptions and technical data, will be sent on request. Machlett Laboratories, Inc., Springdale, Connecticut.



ML-5575/100

Filament Voltage	20.0 volts
Filament Current	24.0 amperes
Maximum Peak Inverse Voltage	150 kv
Peak Anode Current	1.0 ampere
Internal Drop I_b=1.0 Amp. E_f=20.0 Volts	550 volts

MACHLETT

APPLIES TO RADIO AND INDUSTRIAL USES
ITS 50 YEARS OF ELECTRON TUBE EXPERIENCE

MEMBERSHIP

(Continued from page 46A)

Strum, R., 8317—21 Ave., Brooklyn 14, N. Y.
Sunde, D. H., 1614 N. Queen St., Arlington, Va.
Sussenguth, C. E., Cia Standard Electric, Ave. Tomkinson 1700, San Isidro, F.C.C.A., Pcia Buenos Aires, Argentina
Swarthe, E., 5118 Harold Way, Los Angeles 27, Calif.
Swartzlander, G. W., 1220 Stillwell Ave., Fremont, Ohio
Tedder, P. M., Box 2462 University Station, Gainesville, Fla.
Trompeter, E., 706½ W. 81 St., Los Angeles 44, Calif.
Tuma, G., University of Oklahoma, Norman, Okla.
Underwood, B. H. J., 16 Pequegnat Ave., Kitchener, Ont., Canada
Upton, D. J., 135 W. 93 St., New York, N. Y.
Walker, R. E., Dawson St., Mason, Ohio
Wasserman, I. E., 3455 Knox Place, New York 67, N. Y.
Winston, C. B., 3717 E. Fourth St., Dayton 3, Ohio
Wilts, J. R., 717 Home Park Blvd., Waterloo, Iowa
Wissemann, H. J., 415 Sunset Ave., Dallas 8, Texas
Wright, J. J., 9141 S. LaSalle St., Los Angeles 44, Calif.
Yeutter, L. D., 10721 Mansel Ave., Inglewood, Calif.

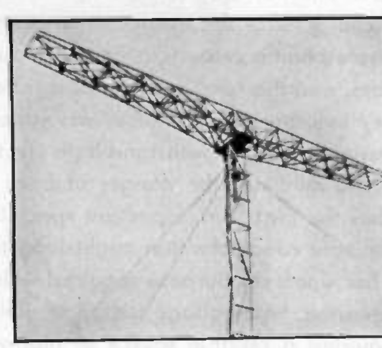
News—New Products

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

(Continued from page 32A)

Rotary Beam Antenna Support

The new Trylon Rotary Beam Antenna Support made by the Wind Turbine Company, West Chester, Pa., offers amateurs an easily installed fully dependable unit for 4-element, 20-meter array. Of lightweight, stainless steel, spot-welded construction the support has an overall length of 19′ 2″ and weighs only 31 pounds exclusive of the mounting assembly. Ball bearing design provides full and easy 360° traverse and the unit is adaptable to either manual or motor drive.



The beam attaches easily to any supporting tower. It is stated that the support can be moved without difficulty from one location to another and can be erected with no tool other than a screwdriver.

(Continued on page 62A)

TRIGGERTUBE...

SYLVANIA'S NEWEST

—made specifically for electronic relay applications...

HERE's a new 5-element, inert-gas filled, internally triggered cold cathode relay tube designed for operation up to 1000 volts on the anode, with a positive pulse on the control or trigger grid—a tube made specifically for triggering.

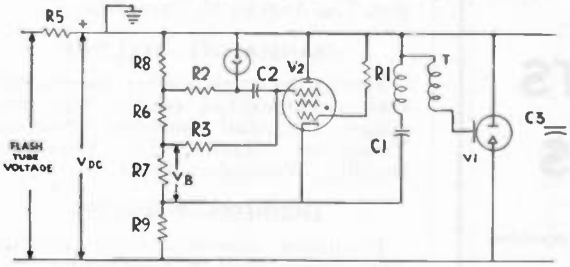
Its cathode structure is similar to that utilized in the well-known 1D21, SN4 type strobotron tubes which are mostly used for stroboscopic applications. This cathode design is characterized by its ability to furnish extremely high instantaneous peak currents—hundreds of amperes.

However, the design of the new Triggertube varies in that the delay time—time required to initiate the arc—as well as the deionization time, is greatly reduced as compared with previous triggering tubes. In addition, since this tube has been especially designed for trigger applications—applications which do not utilize the light flashes produced by the arc—it can be ideally utilized wherever stable characteristics and low switch current are important.

For example: electronic flash equipment in which externally triggered flash tubes can be readily controlled by a hand trip switch, built-in shutter synchronizing switches, or by a photocell.

Write address below for full specifications.

PHOTOCELL TRIPPING CIRCUIT FOR ELECTRONIC FLASH TUBE



R_1	Keep-alive current limiting resistor	20 megohms
R_2	Phototube resistor	0.25 megohm
R_3	Grid current limiting resistor	10 megohms
R_5	Power supply limiting resistor	
R_6, R_7, R_8, R_9	Phototube and Triggertube voltage divider	
C_1	Anode discharge condenser	0.25 μfd.
C_2	Trigger grid condenser	0.01 μfd.
C_3	Flash tube condenser	
T	Ignition coil condenser	
V_B	Trigger grid bias voltage	
V_1	Flash tube type R4330	
V_2	Type OA5 Triggertube	

The OA5 is licensed under the tube patents of Edgerton, Germeshausen and Grier, but no license is implied under their circuit patents.

SYLVANIA ELECTRIC

Electronics Division . . . 500 Fifth Avenue, New York 18, N. Y.

MAKERS OF ELECTRONIC DEVICES; RADIO TUBES; CATHODE RAY TUBES; FLUORESCENT LAMPS, FIXTURES, WIRING DEVICES; ELECTRIC LIGHT BULBS

AIRCRAFT CORPORATION

old established firm has openings for the following technical personnel:

Engineering Technical Writer—B.S. Degree in Aero Engr. or Mech. Engr. Experience in report writing necessary.

Industrial Engineer—25 to 30 years old with 3 to 5 years experience in Administrative Engineering with Industrial Organization.

Two Electrical Engineers or Physicists—M.S. Degrees or better preferred. One with at least four years experience in research or development of television or microwave receivers, the other with equivalent experience on microwave antennas and/or systems.

Two Applied Physicists—M.S. or Ph.D. Degrees, one with at least 3 years experience in Electronics and/or Instrument Design, the other with equivalent experience as an experimental physicist with high vacuum experience.

Two Mathematicians—M.S. or Ph.D. Degree with five years experience in Research and Development Problems."

Reply to Box 446

The Institute of Radio Engineers, Inc.

1 East 79th Street

New York 21, N.Y.

ENGINEER EXECUTIVE

We need a top-flight executive to direct the engineering efforts of our young, expanding electronic manufacturing organization.

Box 447

The Institute of Radio Engineers

1 East 79 St., New York 21, N.Y.

WANTED PHYSICISTS ENGINEERS

Engineering laboratory of precision instrument manufacturer has interesting opportunities for graduate engineers with research, design and/or development experience on radio communications systems, electronic & mechanical aeronautical navigation instruments and ultra-high frequency & microwave technique.

WRITE TO BOX 935

EQUITY ADVERTISING AGENCY

113 W. 42nd St., New York 18, N.Y.

POSITIONS OPEN

The following positions of interest to I.R.E. members have been reported as open. Apply in writing, addressing reply to company mentioned or to Box No. . . .

The Institute reserves the right to refuse any announcement without giving a reason for the refusal.

PROCEEDINGS of the I.R.E.
1 East 79 Street, New York 21, N.Y.

PHYSICIST

With MS or Ph.D. degree, and training in both nuclear physics and electronics. Write in detail, stating qualifications, to Personnel Office, RCA Laboratories, Princeton, N.J.

INSTRUCTORS

To teach Radio Engineering. Must have BS in EE or Physics, or equivalent; 5 years experience in commercial electronics work. Knowledge of microwaves desirable. Write, giving full details regarding education and experience, to Personnel Department, Spartan School of Aeronautics, Tulsa, Oklahoma.

PHYSICISTS AND ELECTRICAL ENGINEERS

Unusual opportunities in recently organized research group for work in broad fields of radio, radar, telemetering, servomechanisms, and gyroscopes. Excellent openings for experienced physicists with good training in fundamentals. Please reply, giving experience and education including transcript of college record, to: Engineering Personnel Office, North American Aviation, Inc., Municipal Airport, Los Angeles 45, California.

TRANSLATORS—PART-TIME

Foreign language articles, papers, patents, etc. Qualified readers state languages, technical subjects. Accurate Translation Service, 711 Woodward Building, Washington 5, D.C.

ENGINEERS—PHYSICISTS

Prominent communications development organization in Metropolitan area has openings for men experienced in microwave systems development; UHF and VHF transmission, receiver and antenna circuits; and electro-mechanical design. Write details Box 444.

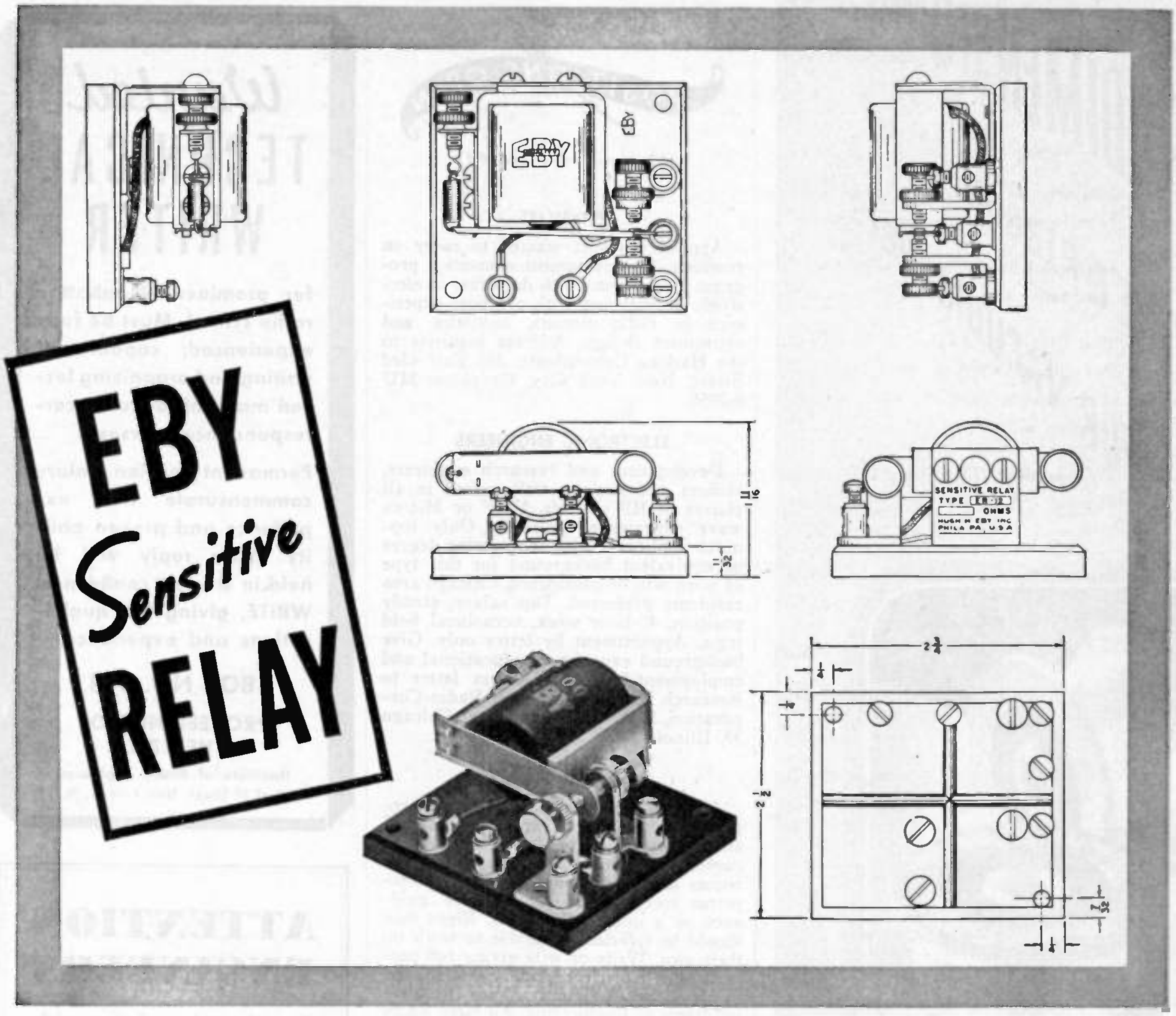
PATENT ENGINEER

Good pay while you learn. An unusual opportunity for a young electrical engineer or physicist to receive intensive training as a patent solicitor for a substantial Texas corporation. Give details of experience, education, draft status, salary expected. Box 445.

PHYSICIST-METALLURGIST

For fundamental development and research in metals used in electron tubes. Work requires a high degree of theoretical background as well as practical experience. Location near metropolitan area with ample facilities available for extensive research. State complete resume of experience and background. Box 440.

(Continued on page 52A)



APPLICATION:

The EBY sensitive relay is designed for direct current (full or half-wave rectified) control circuits where the available power for operation is relatively small. Its low power consumption for positive operation makes it ideal for installation in photoelectric control equipment, vacuum tube amplifier circuits and to protect delicate contacts of sensitive control instruments.

MAGNETIC CIRCUIT:

The EBY sensitive relay, because of the advanced design of the armature, and by the use of a high quality, special steel alloy in the magnetic circuit, has the outstanding features of low power requirement for positive action and its unusually high speed of response.

COILS:

The EBY sensitive relay can be supplied with five different coil sizes covering most of the operational needs in sensitive relay control applications. The standard coil values are: 300, 1000, 2500, 5000 and 10,000 ohms resistance. The relay is rated at 11.25 milliwatts for positive operation; however, it can be adjusted for less when needed. The coils will safely carry 2 watts.

CONTACTS:

Contacts, single-pole, double throw, are of coin silver and are rated to carry 2.5 amperes at 115 volts A.C., or 0.5 amperes at 115 volts D.C. The contact air gap and spring tension are adjustable for critical applications.

BASE:

Molded phenolic.

HUGH H.
EBY
INCORPORATED
18 W. CHELTEN AVE.
PHILA. 44, PENNA.

POSITIONS OPEN

(Continued from page 50A)

PHYSICIST

Applied physicist wanted to carry on research in government-sponsored program. Prefer man with doctorate in electronic physics and with practical experience in radio circuits, acoustics, and instrument design. Address inquiries to the Haskins Laboratories, 305 East 43rd Street, New York City. Or phone MU 5-7956.

ELECTRONIC ENGINEERS

Development and research engineers, seniors and juniors, well versed in all phases of RF circuits. VHF or Microwave experience desirable. Only topnotch applicants with engineering degree or equivalent background for this type of work will be considered. Chicago area residents preferred. Top salary, steady position, 40-hour week, occasional field trips. Appointment by letter only. Give background experience, educational and employment history. Address letter to Research Division, Belmont Radio Corporation, 5921 W. Dickens Ave., Chicago 39, Illinois.

RADIO ENGINEERS

Air King has openings for graduate engineers with Senior experience on AM and FM broadcast receiver design. Applicants must be schooled in measuring techniques and capable of establishing competent specifications for Vendors' guidance on a quantitative basis. Right men should be sufficiently capable to work on their own. Write or wire giving full particulars of experience, salary desired, etc. to Mr. Frank A. Hinners, Vice President in Charge of Engineering, Air King Radio Co., 1523-63rd St., Brooklyn 19, N.Y.

COIL DEPARTMENT HEAD

Experienced in set-ups, winding, impregnation and testing home receiver type RF and IF coils and chokes, wanted by television and radio manufacturer in New York area. Give experience and salary expected. Box 442.

ENGINEER—EXECUTIVE

We need a top-flight executive to direct the engineering efforts of our young, expanding electronic manufacturing organization. Box 447.

ENGINEERS

Prominent Aircraft Company, Eastern United States, needs men with following qualifications: Experienced engineers with Bachelor's, Master's, Doctor's degrees in Electrical Engineering, Physics, Mathematics. At least two years experience in design and development of radar and television systems, automatic computers, servomechanisms, target seekers, etc., required. Positions open for preliminary and detail design, research, and development of guided missiles under Army and Navy contracts. Starting salary commensurate with experience. Address Box 441.

(Continued on page 54A)

Wanted TECHNICAL WRITER

for prominent Manhattan radio school. Must be fully experienced; capable of writing and organizing lesson material for radio correspondence courses.

Permanent position. Salary commensurate with experience and proven ability. Your reply will be held in strictest confidence. WRITE, giving full qualifications and experience.

BOX NO. 443

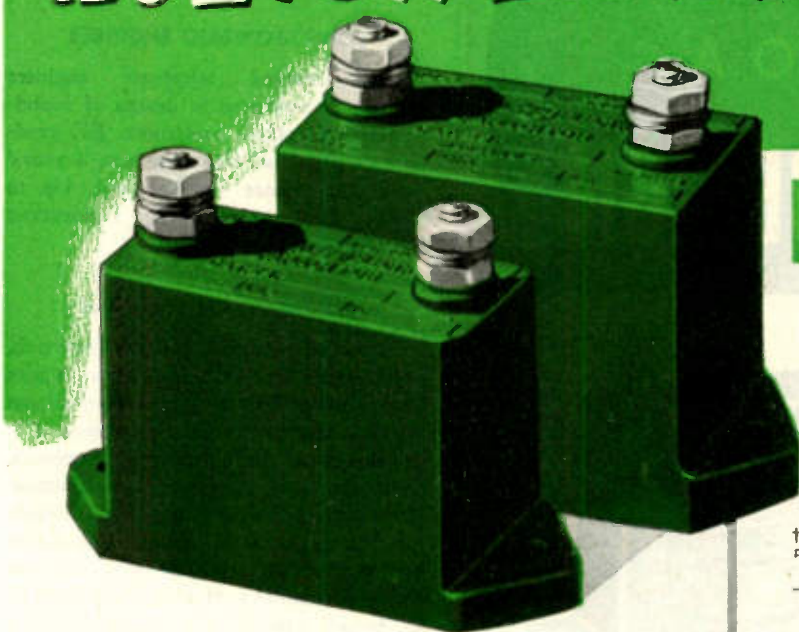
PROCEEDINGS OF THE I.R.E.

(Institute of Rodio Engineers)
1 East 79 Street, New York 21, N.Y.

ATTENTION ENGINEERS

Experienced engineers with Bachelor's, Master's, or Doctor's degrees in Electrical Engineering, Communications, Radio, Physics, Mathematics. At least two years experience in design and development of radar and television systems, electronic navigational systems, automatic computers, servomechanisms, etc., required. Specialists in High Frequency transmitters, receivers, antennas, aircraft electronic components particularly desired. Starting salary commensurate with experience. Exceptional opportunity for the right men. Write McDonnell Aircraft Corporation, Lambert-St. Louis Municipal Airport, Box 516, St. Louis (21) Missouri.

G.E. OFFERS
Lectrofilm Capacitors
at New Low Prices!



. . . Permits Use of Larger MUF Sizes in R-F Circuit Design without Cost Penalty

Here's a capacitor price reduction that really means something to circuit designers: *G-E offers all listed ratings of case-style 65 Lectrofilm* blocking and by-pass capacitors at one new price, approximately half of the previous level. Similarly, all listed ratings of case 70 designs are offered at one new, low price!*

This means that you no longer have to place cost ahead of good circuit design. It means that you now have complete freedom to use either *high* or *low* capacities in R-F blocking and by-pass applications—without paying a premium for higher capacity!

General Electric's development of Lectrofilm, a new capacitor dielectric, and the advanced methods used in manufacturing these capacitors have resulted directly in these new low prices. *Lectrofilm capacitors are now the answer to new circuit economies, better circuit designs, lower over-all equipment costs.*

Write for Bulletin GEA-4295A, *Apparatus Dept., General Electric Company, Schenectady 5,* N. Y.

**Reg. U.S. Pat. Off.*

NEW LOW PRICES OF G-E LECTROFILM CAPACITORS†

					Cap Muf	Rated D-c Voltage
Quantity Case 65	1 to 9	10 to 99	100 to 999	1000 or more	.0001 .001 .01	3000 3000 1000
Net Price	6.50	4.90	3.90	3.25	.1	500
Quantity Case 70	1 to 9	10 to 99	100 to 999	1000 or more	.0001 .001 .01	5000 5000 2000
Net Price	8.45	5.85	4.55	4.25	.1	750

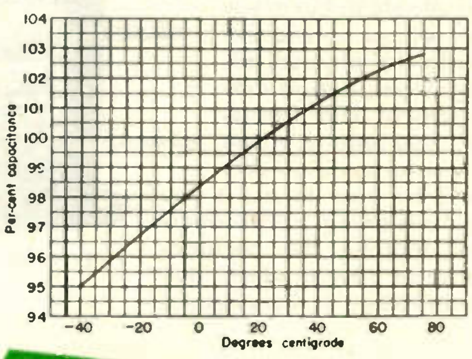
†Prices to manufacturers purchasing Lectrofilm Capacitors for use with their product will be supplied on inquiry.

RATINGS AT HIGH TEMPERATURE

Ratings are based on 25 C ambient temperatures. For other ambient temperatures the following derating factors must be used:

Ambient Temp. C	Per Cent Rated D-c Volt.	Per Cent Rated Superimposed RMS Sine Wave Current
25	100	100
30	99	95
35	98	85
40	97	80
45	96	75
50	95	70
55	94	60
60	93	50
65	92	45
70	91	35
75	90	15

Good Capacitance-temperature Characteristics at low cost



G-E Lectrofilm Capacitors for Radio and Industrial Electronic Equipment

GENERAL ELECTRIC

407-115-5700

POSITIONS OPEN

(Continued from page 52A)

ENGINEERS (SENIORS)

ELECTRICAL. Several positions open for men with UHF experience.

MECHANICAL. Several positions open for men with radar design experience. Allen B. Du Mont Laboratories, Inc., 2 Main Avenue, Passaic, N.J.

SOUND-POWERED ENGINEER

Sound-powered telephone engineer wanted. Experienced in design of sound-powered telephone equipment. EE graduate or physicist with minimum 4 years' design experience in this field. Up to $6000. Long established Connecticut manufacturer. Box 439.

ENGINEERS—TECHNICIANS

Expanded guided missile research, manufacture, and experimentation require long term services of a new development group in the Electronics Department. Positions open for graduate engineers, physicists, and experienced technicians. Masters and Doctors degrees desirable for better positions. Educational background in mathematical-physics, electronics, aerodynamics preferred. Work will be on broad aspects of electronic servo mechanism control systems. Salaries $2500-$8000, commensurate with ability. Location Farmingdale, Long Island. Communicate with A. E. Sutton, Pilotless Plane Division, Fairchild Engine and Airplane Corporation, 184-10 Jamaica Avenue, Jamaica 1, N.Y.

RADIO ENGINEER

Needed for extensive laboratory development work in circuit detailed investigation and design of RF components. Must have experience in experimental radio or allied techniques. Write to: Employment Department, The F. W. Sickles Company, Chicopee, Mass. Give full particulars as to experience, salary desired, etc.

ASSOCIATE PROFESSOR OF ELECTRICAL ENGINEERING

Man with MS in Electrical Engineering with specialization in electronics to take charge of Electronics Option. Teaching experience required. Industrial or military experience desirable. Salary $3200 to $3600, for nine month school year, depending on age and experience. Write: Department of Electrical Engineering, North Dakota Agricultural College, Fargo, North Dakota.

(Continued on page 56A)

SOUND EQUIPMENT—*precisionized*—**mechanically and electronically**—*for finer performance*

Unit 524 Transcription Turntable

Fairchild is now in a position to accept additional orders for the NEW Unit 524 Transcription Turntable on a 30-day delivery basis.

Here again, Fairchild has anticipated the needs of FM with the Unit 524 Transcription Turntable. It's completely new. It offers 'WOW'-free performance without turntable noise, rumble or vibration for either FM or AM recorded broadcasts; for dubbing from disc to disc, or to film; and for laboratory uses where extraneous noise and distortion cannot be tolerated. It has been engineered for wide dynamic range, minimum distortion content and wide frequency range—*to keep the record alive!*

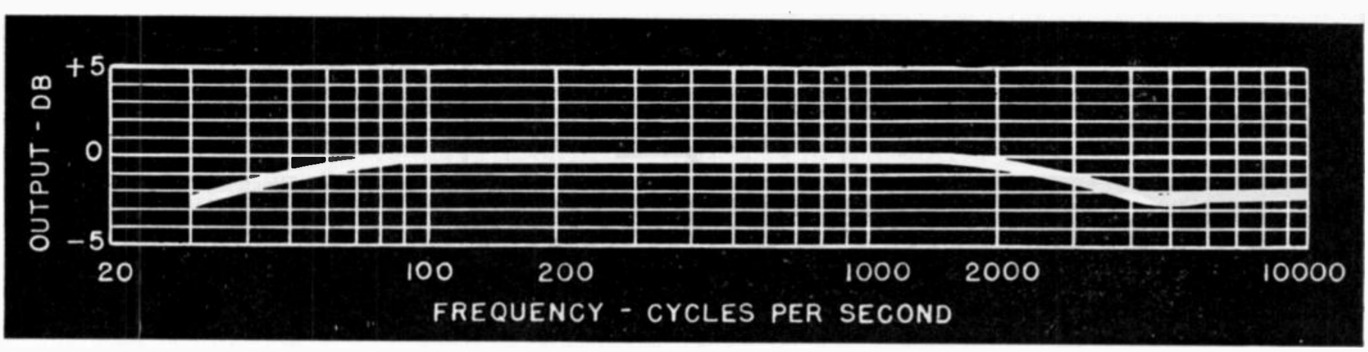
The drive and turntable have been newly designed for cabinet installation. They are *not* portable units set in a console. A vibration-proof rubber coupling connects the synchronous motor and drive which are spring mounted and precision aligned in a single heavy casting—*at the bottom of the cabinet*—as shown in the illustration above.

'WOW'-free operation is assured at either 33.3 or 78 rpm by a carefully maintained evenness of speed. Split-second timing is guaranteed by the positive Fairchild direct-from-the-center turntable drive. 30 to 10,000 cycle frequency response is provided by Fairchild's patented 25 gram 'floating' pressure Lateral Dynamic Pickup—*as shown below in the typical production line frequency-response curve!*

For complete information address: 88-06 Van Wyck Blvd., Jamaica 1, N. Y.

SOUND EQUIPMENT

Fairchild CAMERA AND INSTRUMENT CORPORATION



Positions Wanted By Armed Forces Veterans

In order to give a reasonably equal opportunity to all applicants, and to avoid overcrowding of the corresponding column, the following rules have been adopted:

The Institute publishes free of charge notices of positions wanted by I.R.E. members who are now in the Service or have received an honorable discharge within a period of one year. Such notices should not have more than five lines. They may be inserted only after a lapse of one month or more following a previous insertion, and the maximum number of insertions is three per year. The Institute necessarily reserves the right to decline any announcement without assignment of reason.

ENGINEER

BEE, Cooper Union. Age 24, married. Radar training Harvard-M.I.T. 26 months signal corps radar officer. 10 years licensed radio amateur, class "A" license. Interested research or development on radar or communications equipment, New York City or vicinity. Julian D. Hirsch, 18 Edgewood Park, New Rochelle, N.Y.

ENGINEER

BS-EE. Graduate study. Age 25, married. 3 years civilian development experience in MAD, receivers, and radar. Present duty: radar equipment development. Available January 1, 1947. Box 54W

PRACTICAL ENGINEER

Technician, with general knowledge of radio engineering principals. Fifteen years radio work, mostly broadcast construction and maintenance. Age 37. Desires work as assistant to experienced professional engineer. Box 55W.

ELECTRICAL ENGINEER

BS-EE, University of Kansas, 1942. Age 25, single. One year experience design of HF and VHF portable radio equipment. Forty-five months Signal Corps experience with telephone and teletype inside-plant equipment and multi-channel VHF radio link equipment. Box 56W.

COMMUNICATION ENGINEER

Commander USCG, graduate U. S. Coast Guard Academy 1933. MS in Communication Engineering Harvard 1942. Varied radio and electronic experience. Desires position in the Boston area. Available December. Box 57W.

ENGINEER

Master of Electrical Engineering, age 37, single, desires suitable position in international engineering sales. Fluent French, German, Italian; some Spanish. Good appearance and personality. Foreign fields preferred. Box 58W.

(Continued on page 58A)

Positions Wanted

(Continued from page 56A)

ENGINEER

BEE, age 23, single, 2 years industrial experience, 1 year UHF research. Desires position New York City or environs, preferably in UHF field. Available January. Box 59W.

ENGINEER

BEE. Some graduate work. Age 26. 4 years Field Engineer Signal Corps. 1 year design electrical test equipment and redesign surplus property. 1 year coordinator field activities, test and instrumentation new fire control radar U. S. Army. Prefer East. Box 60W.

RADIO OR SALES ENGINEER

Bowdoin, M.I.T., Corpus Christi Navy electronics training, four years officer, aviation electronics duties. R.C.A. Institute Technology, manufacturing and broadcasting experience. Project Engineer M.I.T. Radiation Laboratory. Box 61W.

ELECTRONIC DEVELOPMENT—INSTRUCTOR

BEE 1943, Cooper Union, UHF graduate theory. Studying N.Y.U. evenings. 1 year civilian experience UHF development. Organized and instructed army radar school. Civilian radio instructing. Desires part time instructing, research or development. Box 40W.

BEGINNING ENGINEER

BS in EE, Tufts College. Age 22, single. 1 year experience in the installation and maintenance of teletype equipment in the Navy. Box 41W.

SALES ENGINEER

Completed Navy Officer Radar course at Bowdoin College and M.I.T. Member of Tau Beta Pi, Eta Kappa Nu. Age 23. Desires position with Mid-West firm along lines of engineering administration or sales engineering. Box 42W.

ENGINEER

BEE 1943. Former Naval officer. Two years Navy experience special supersonics equipment. One year civilian experience, design of electronic marine equipment. Particularly interested in rocket research or development. Box 43W.

JUNIOR ENGINEER

BS in Engineering, majored in electrical. Desires position in New York area in communications or UHF field. Age 23. Ensign USNR (inactive) Box 44W.

PRACTICAL ENGINEER

BS in EE, Illinois Institute of Technology, final tested, as U.S.N. inspector, all types radar at Western Electric Company, Chicago, 1941-44. As Lt. (j.g.) installed GCA fixed blind landing radar unit in Florida. Ham 12 years. Hold commercial phone 1st. Age 28, married. Details on request. Box 45W.

(Continued on page 60A)

Positions Wanted

(Continued on page 58A)

ENGINEER

3½ years EE. Age 31, married. Varied and colorful Naval radio career. Radiotelegraph 1st and Radiotelephone 1st class licenses since 1940. Prefer joining small progressive concern. Box 46W.

ELECTRONICS ENGINEER

BEE 1943. Army radar officer, trained M.I.T. Desires research development or testing in electronics New York area. Age 25. Henry L. Pernick, 1120 Wyatt St., Bronx 60, New York.

NAVAL OFFICER

Age 28, married. Three years Naval radar, Chief Petty Officer. First class radiotelephone and telegraph since 1939. Experienced in transmitter maintenance both FM and AM. Box 30W.

SALES OR SALES ENGINEER

Coast Guard electronics officer, age 27, five years military experience, pre-war electronic sales. Excellent sales record in industrial field since discharge. Will go anywhere in United States or foreign. Box 32W.

ELECTRICAL ENGINEER

BS in EE, graduate work at University of Pennsylvania. Three and one-half years civilian experience in design, development, and production of radio, radar, and electronic equipment. Radio engineering or production engineering position desired. A. F. Driesman, 2169 Pacific St., Brooklyn 33, N.Y.

ENGINEER

BEE 1943, some postgraduate work. 1½ years ciivlian experience in design and construction of electronic instruments for ballistic measurements. U. S. Army Ordnance; 1½ years abstracting German technical documents. Available October. Box 33W.

TWO-WAY RADIO AND MICROWAVES

Well-known highly experienced engineer, investor and author on two-way radio and microwaves. Long successful record pre-war and in Navy. Available for top-flight technical or administrative position in field engineering, sales, research or production. Minimum salary $7200. Any location. Box 28W.

ENGINEER

Living in South Africa, diploma Professor Barkhausen (Dresden); AM. (S.A.) I.E.E. seeks position with American manufacturing concern. Box 29W.

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 48A)

Studio Recorder

The Fairchild Camera and Instrument Corporation, Jamaica, N. Y., announces its No. 523 Studio Recorder, designed to meet the exacting requirements of commercial recording studios and the radio industry

for instantaneous or wax recordings; and of the sound film industry for dubbing sound from disk to film. The table accommodates 18-inch flowed wax masters, acetate, or thicker wax masters. The positive 33⅓ rpm drive assures accurate timing with its synchronous motor—which also makes the A.C. line the only interlocking device needed for dubbing sound.

Fairchild's No. 541 magnetic cutter-head, microscope and mount, in combination with the precision-built lead screw mechanism, develops uniform cutting at any pitch from 80 to 160 lines, either in-out or out-in.

10 Watt Monitoring Amplifier

A high fidelity 10-watt monitoring amplifier for AM or FM use is now being manufactured by Raytheon Manufacturing Company's Broadcast Equipment Division of Chicago. Designed for all monitoring, audition, recording and playback applications, the Raytheon model RM-10 is also well suited for use in a transcription playback booth because of its high gain, low distortion and excellent frequency characteristics.

This new unit is designed for standard relay rack or cabinet mounting and requires only 10½ inches of vertical panel. The amplifier and heavy duty power supply are mounted on a common vertical chassis. The frequency response is substantially flat from 30 to 15,000 cycles.

(Continued on page 64A)

SOLITE★ CAPACITORS

new! startlingly smaller!

ACTUAL SIZE 1 MF, 200 WVDC

TODAY'S trend to ultra-compact electronic designs strides forward with this remarkable, new Solar development in truly tiny paper capacitors.

*SOLITE** Capacitors, utilizing a unique, revolutionary self-healing metallized paper construction, occupy approximately one-third to one-fourth the volume of equivalent conventional multi-paper capacitors. There is a similar saving in weight.

A comparison of typical ratings in tubular types tells its own story:

Dimensions in Inches							
Capacitance	WVDC	SOLITE		Conv. Design		Weight in Ounces	
(mf)		Length	Diam.	Length	Diam.	SOLITE	Conv. Design†
0.1	200	5/8	3/8	1 5/8	1/2	0.08	0.32
0.5	200	1 1/8	15/32	2	11/16	0.13	0.75
1.0	200	1 1/8	17/32	2 1/2	13/16	0.26	1.15
1.0	400	2 1/8	11/16	2 1/2	1	0.69	1.75

† Based on aluminum foil construction. Lead foil capacitors will be still heavier.

*SOLITE** Capacitors are available in both non-metallic and metallic housings in standard d-c voltage ratings up to 400 volts. *SOLITE** Capacitors are also supplied for alternating current applications.

Pilot quantities of *SOLITE** Capacitors may be had immediately. Solar is prepared to discuss delivery schedules of production quantities for your use in those specific applications where you can take best advantage of this important new advance in the capacitor art.

Full details of *SOLITE** Capacitors may be obtained on letterhead request from: Solar Manufacturing Corporation, 285 Madison Avenue, New York 17, N. Y.

"WHEN SPACE IS TIGHT, USE *SOLITE*"

* Trade Mark

Solite Capacitors are fully protected by U.S. letters patent and patents pending.

SOLAR

SOLAR CAPACITORS

"Quality Above All"

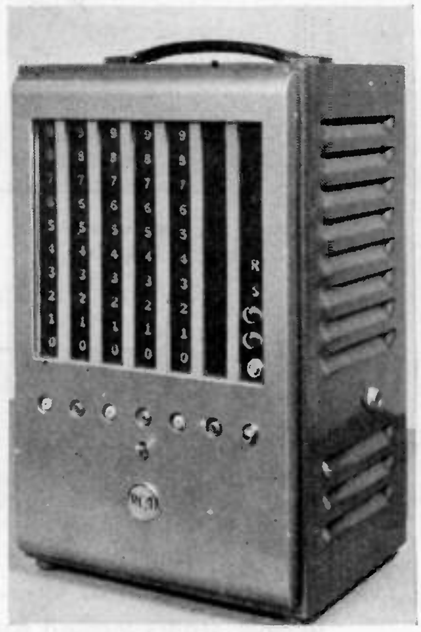
News—New Products

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)

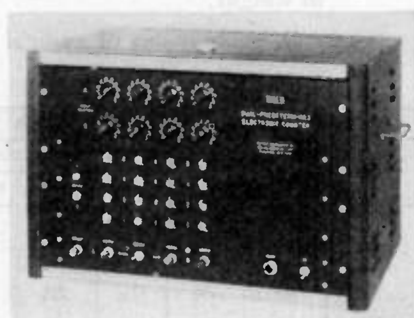
Electronic Counters

Both the Radio Corporation of America, Camden, N. J., and the Potter Instrument Co., 136-56 Roosevelt Avenue, Flushing, N. Y., have announced the release of electronic counters for industrial and scientific



counting. The RCA unit (pictured above) may be utilized to measure velocities and accelerations for intervals up to one second in steps of one micro-second, or to count at speeds as high as 1,000,000 per second.

The Potter Instrument unit (pictured below) will count at a rate of 12,000 per minute. This instrument incorporates a pre-setting device and either single or dual predetermining channels.



It is pointed out by both manufacturers that these electronic counters are particularly suited for operations too fast for conventional counters and find wide industrial applications in processes such as packing pills, starting or stopping operations after a predetermined count, and controlling the length and spacing of the fasteners on slide fasteners.

(Continued on page 65A)

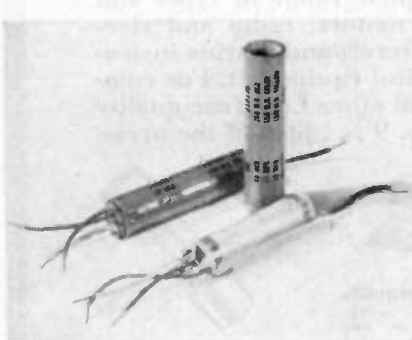
News—New Products

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

(Continued from page 64A)

Capacitor Plastic Film Wrap

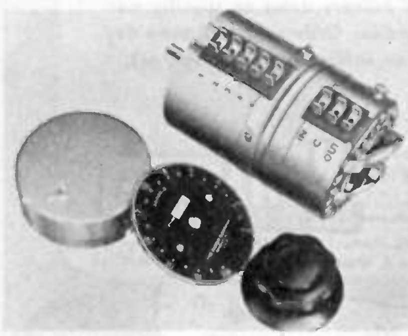
A new plastic-film inner wrap for dry electrolytic capacitors to retard evaporation of the electrolyte and serve as a barrier against contamination from salts from the cardboard housing has recently been developed by the Celanese Products Corpora-



tion and Solar Manufacturing Corporation, 285 Madison Ave., New York 17, N. Y. Increased operating life is claimed for Solar Types DS, DT and DH dry capacitors which utilize this new type of construction.

Tone Compensating Attenuator

Essentially a ladder network designed so that the frequency characteristics follow the hearing response curves of the human ear, Type LAC-720, tone compensating attenuator has been designed by The Daven Company, 191 Central Avenue, Newark, N. J. By proper external connections it is possible to obtain six different Attenuation vs. Frequency curves from the "human-ear type of response" to a flat frequency response. When the unit is wired for a flat frequency response it functions as a straight ladder of 2.5 db per step.



It is suggested by the manufacturer that this new tone compensating attenuator will find applications in psychological and physiological testing and experiments in hearing perception, and in research and development in the study of music appreciation.

(Continued on page 66A)

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 65A)

Recent Catalogs

• • •On Graphic Recorders and Accessories, by **Sound Apparatus Co.**, 233 Broadway, New York 7, N. Y. Catalog No. 1.

• • •On Advanced Courses in Powder Metallurgy (lecture and laboratory), by College of Engineering, **New York University**, New York 53, N Y.

• • •On Vacuum Indicating and Recording Instruments, by **George E. Fredericks Co.**, Bethayres, Pa. Bulletin No. R101.

• • •On Photoelectric and Electronic Controls, by **Photoswitch, Inc.**, 77 Broadway, Cambridge 42, Mass. Bulletin 504.

• • •On Multiple Drilling and Tapping Equipment, by **Ettco Tool Co.**, 594 Johnson Ave., Brooklyn 6, N. Y. Bulletin No. 31.

• • •On "School Sound Systems"—a compilation by the **U. S. Office of Education** of what equipment schools may obtain, what specifications schools should insist upon, and architectural helps for designers of modern school buildings. The booklet is published by the **Radio Manufacturers' Association**, 1317 F St., N.W., Washington 4, D. C.

• • •On Types and Characteristics of Microphones (Catalog No. 155) and Crystal Phonograph Pickups (Catalog No. 156), by **Shure Brothers**, 225 West Huron St., Chicago 10, Ill.

• • •On Multiple Contact Terminal Blocks, by **Cannon Electric Development Co.**, 3209 Humboldt St., Los Angeles 31, Calif. Catalog No. Y6-1.

• • •On Fiberglas Insulating Tubing, by **Bentley, Harris Mfg. Co.**, 1002 Bentley St., Conshohocken, Pa. Bulletin No. P-14.

• • •On Fractional Horse-Power Gears, by **Gear Specialties**, 2635 W. Medill Ave., Chicago 47, Ill. Bulletin No. 1046.

• • •On FM-TV "Di-Fan" Antenna, by **Andrew Company**, 363 East 75 St., Chicago 19, Ill. Bulletin No. 45.

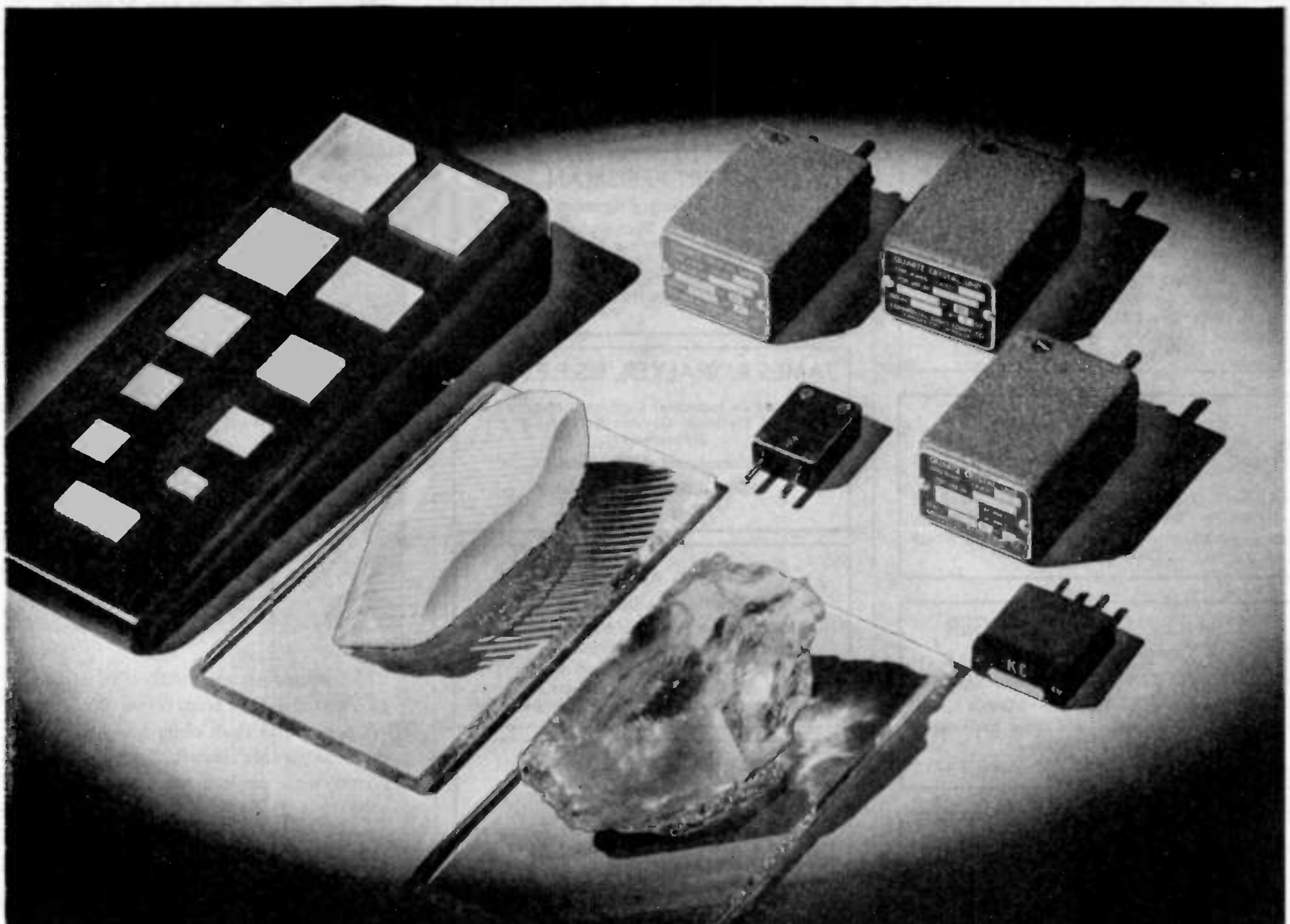
• • •On Crystal Controlled Oscillator, by **Bliley Electric Co.**, 227 Union Station Bldg., Erie, Pa. Bulletin No. 32.

• • •An INDEX to Radio Service Diagrams, by **Supreme Publications**, 9 So. Kedzie Ave., Chicago 12, Ill.

• • •A MANUAL on Cathode-Ray Oscillographs, by **Allen B. DuMont Laboratories, Inc.**, 2 Main Ave., Passaic, N. J. Manual No. 274.

• • •On Thermosetting Silicone Resin, by **Dow Corning Corp.**, Midland, Mich. Bulletin No. DC-2103.

(Continued on page 68A)



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 66A)

• • •On Terminals and Lugs, by **Aircraft Marine Products, Inc., 1523 No. Fourth** St., Harrisburg, Pa. Bulletin No. 1946.

• • •On FM Equipment, by **Radio Engineering Laboratories, Inc., 35-54 36th** Street, Long Island City 1, N. Y. Bulletin No. 5015.

• • •Two Marketing Surveys, by **The Crowell-Collier Publishing Co.,** 250 Park Avenue, New York 17, N. Y. "Radios and Records" and "Automobiles, Radios and Electrical Appliances."

• • •On Miniature Synchronous Motors, by **The R. W. Cramer Co., Inc.,** Centerbrook, Conn. Bulletin No. 10.

• • •On Universal Link Joints, by **Piezo Manufacturing Corp., 110 East 42 St.,** New York 17, N. Y. Bulletin No. 45B.

• • •On Capacitors for Photoflash Photography, by **Sprague Electric Company,** North Adams, Mass. Bulletin No. 3205.

• • •On Precision Variable Resistors, by **Technology Instrument Corp.,** 1058 Main St., Waltham 54, Mass. Bulletin No. RV-46.

• • •On Operation and Applications of Seam Welders, by **Progressive Welder Co.,** 3050 East Outer Drive, Detroit 12, Mich. Bulletin No. 803.

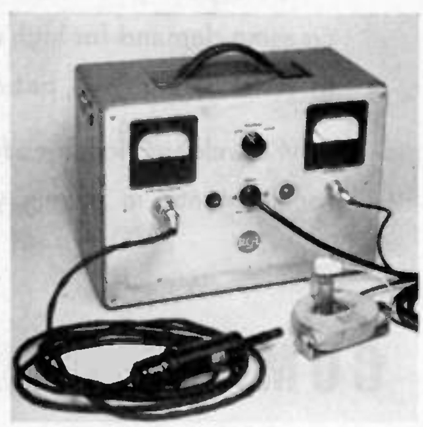
New Ten-Ampere Variac

Coinciding with the capacity of #14 copper wire leads, a new group of Variacs, rated at 10 amperes with a 15-ampere maximum, has been announced by General Radio Company, 275 Massachusetts Avenue, Cambridge 39, Mass.

The manufacturer states that these V-10 Variacs deliver from 60 to 100% more KVA per pound than older models due to a more favorable distribution of copper and iron, with low-loss core material.

Electronic Vacuum Gage

A radically new vacuum measuring gage, designed for operations requiring continuous and accurate measurements of reduced pressures as low as 0.1 micron, is in production and will be available soon, it was announced by the Scientific Instrument Section, Radio Corporation of America, Camden, N. J.



Made virtually indestructible through the use of non-burn out elements, the new instrument has proven its dependability by four year's operation as a component of the RCA Electron Microscope. This gage, designated as type EMG, has now been developed as a separate, easily portable unit, designed especially for modern vacuum systems in which rotary pumps are used to back oil diffusion pumps.

(Continued on page 69A)

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 68A)

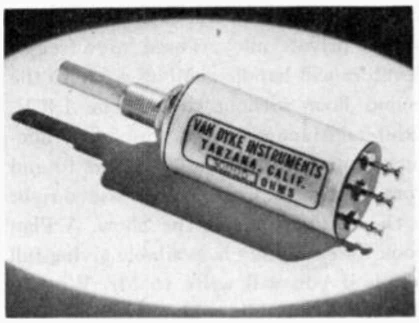
Plant Expansions

• • • At New York, N. Y., by **Newark Electric Co.,** 115 W. 45 St., New York 19, N. Y., totaling 20,000 square feet, for warehouse facilities.

• • • At Anaheim, Calif., by **General Electric Co.,** (Chemical Department), Pittsfield, Mass., totaling 35,000 square feet, for the production of Glyptal alkyd resins.

Helical Potentiometers

Immediate delivery is promised by the Van Dyke Instruments Company, Tarzana, Calif., of their new light-weight, linear, wire-wound resistor of the helical type. Linearity of the completed resistance is maintained by electronic control during the winding process and the use of low temperature coefficient resistance wire.



Due to its small size and light weight the potentiometer is especially adapted to aircraft instrumentation, electronic calculators and similar applications. Five and ten turn units are standard and units having odd numbers of turns can be supplied.

Chicago Two-Way Radio Taxis

The first two-way radios to be used in Chicago taxi cabs were put in operation recently by the Veterans' "Flash" Cab Company. This equipment was made and installed by the Galvin Manufacturing Corporation.

Both the Motorola transmitter and receiver in the new sets are crystal-controlled, the crystal used being already compensated for changes in temperatures, so that it is always on frequency regardless of weather conditions. Another feature is the use of tuned lines in the receiver instead of the customary "lumped" circuits.

All drivers are being instructed to report by radio all fires, accidents, and other emergencies sighted during their rounds. In this way, it is thought that such emergencies can be reported to the fire and police departments in shorter time.

(Continued on page 72A)

Grand Central Palace Obtained for 1947 Radio Engineering Show

By good fortune, a change in schedules has made the Grand Central Palace at 46th Street and Lexington Avenue available to The Institute of Radio Engineers for sessions and exhibits of the National Convention, March 3–6, 1947. Greatly improved exhibit facilities and additional session halls will result from the change in plans.

Nearer Headquarters Hotel

The Palace is only four short blocks north of The Hotel Commodore, in which the banquet and largest sessions will be held. It can be reached by tunnels with only one street to cross. Both places are on Lexington Avenue.

No Limits on Exhibits

Exhibitors were sharply limited at the Armory by lack of space. The Palace provides not only enough space for all exhibitors without ration restrictions, but also room for at least two technical session halls of 450 seats each on the third floor. Some exhibitors have doubled and tripled the size of their exhibits on being advised of the change. No firm with an exhibit of interest to engineers will be barred by lack of space.

I.R.E.'s Largest Show

Already 152 manufacturers have reserved space for exhibits. More than 27,000 square feet of exhibit space was needed, and the 34th Street Armory could provide only 14,400. The area which will be taken at Grand Central Palace will nearly double that of exhibits at the Hotel Astor in January 1946. The Radio Engineering Show provides the radio-electronic industry a genuine service in bringing engineers and manufacturers together. The exhibits at the 1947 Show will highlight the gains of wartime research in post-war radio engineering equipment and products. The exhibits are for engineers and home radios will not be shown.

Improvements for Visitors

Aisles from ten to thirteen feet wide, four stairways, elevators, large checkrooms and all the advantages of New York's finest exhibition building will serve the convenience of engineers attending the Convention and visiting the exhibits. With sessions and exhibit hours extended to four days, Monday, March 3 through Thursday, March 6, it is expected that our engineers will have more time to visit the exhibits and attend the technical sessions that interest them.

Improvements for Exhibitors

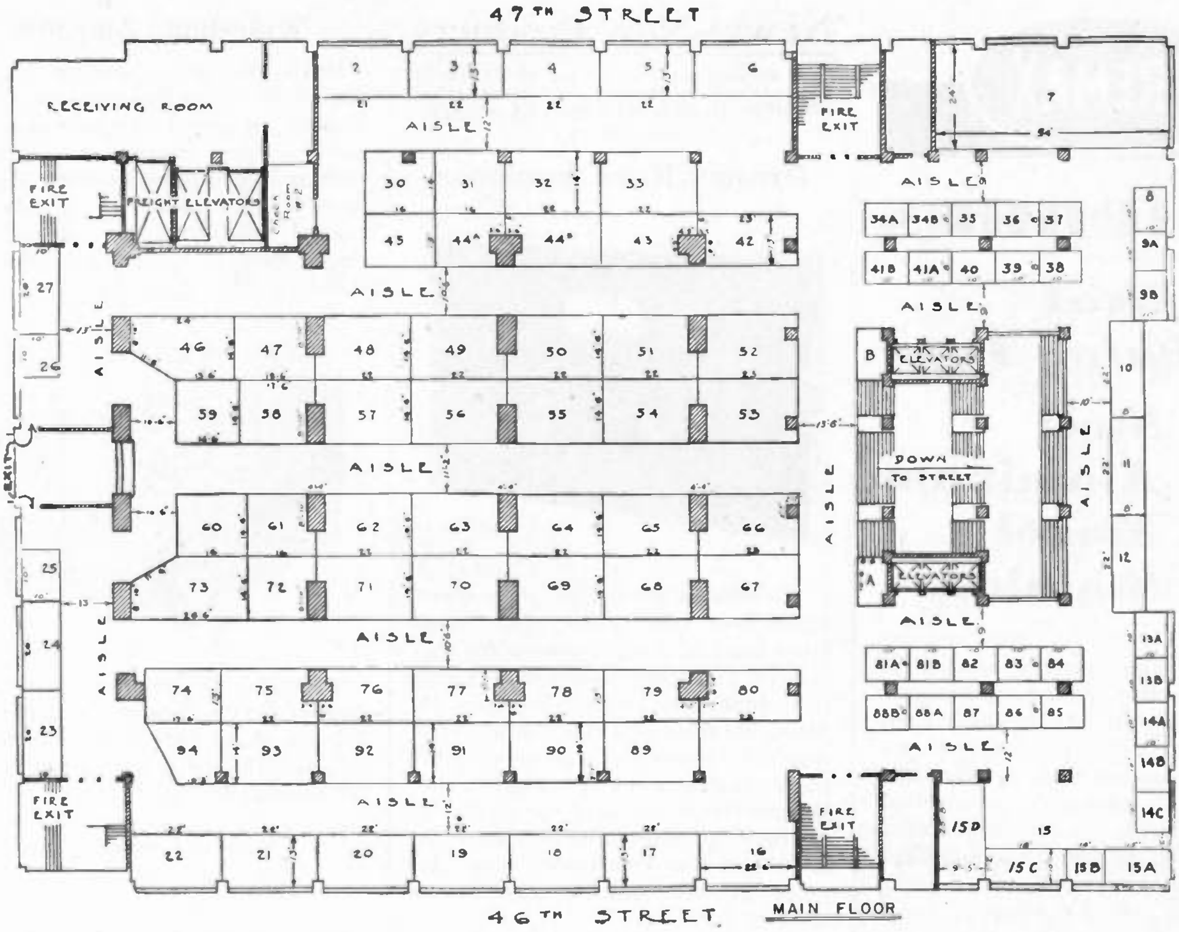
At Grand Central Palace, exhibitors get three full days to set-up exhibits, and three days for removal. The receiving platform is able to handle six trucks at a time, and is on a private alley. Three large freight elevators will handle exhibits going to the second floor without delay. The I.R.E. Exhibits Management is providing adequate manpower for moving cases to and from the booths. Cases will be stored right in the building during the Show. A Plan Book for exhibitors is available giving full details if you will write to Mr. Wm. C. Copp, I.R.E. Exhibits Manager, 303 West 42nd Street, New York 18, N. Y.

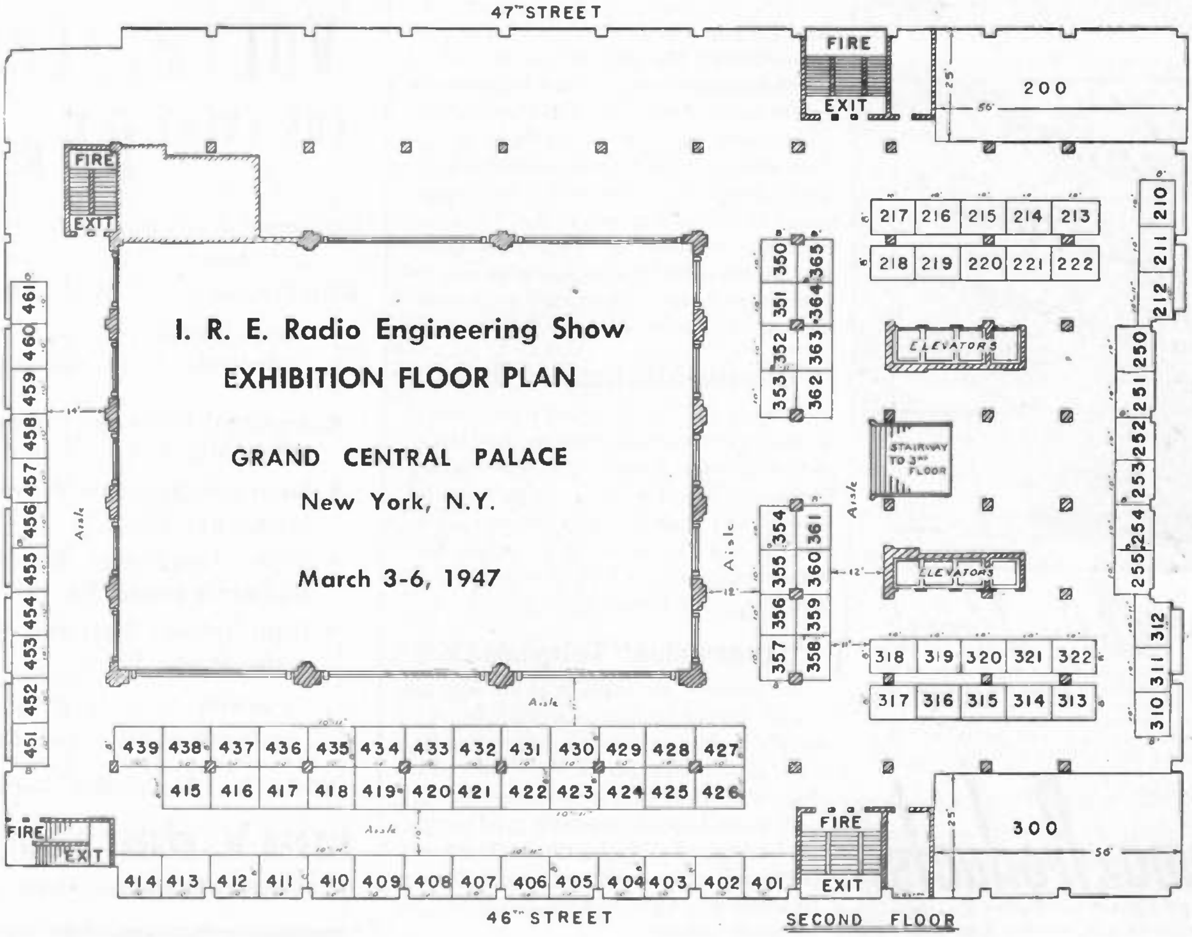
Exhibit space rents at $3.12½ per square foot for regular units and $4.00 for preferred locations. A floor plan is available on request, in larger scale than the one shown on the facing page.

Watch "Proceedings" for News

Additional data on the 1947 Convention will appear in the January issue, and a preliminary program of papers and news of speakers in the February Issue. Out-of-town members can register for hotel space now by writing to the New York Convention and Visitor's Bureau, 233 Broadway, New York City. The basic reason for choosing the March 3 to 6 dates was to obtain better hotel accommodations for our out-of-town visitors. A mailing to all I.R.E. members giving program information and banquet ticket order form will be made in January.

Those wishing to submit papers for technical sessions may address Prof. Ernst Weber, c/o The Institute of Radio Engineers, 1 East 79 Street, New York 21, New York.





I. R. E. Radio Engineering Show

EXHIBITION FLOOR PLAN

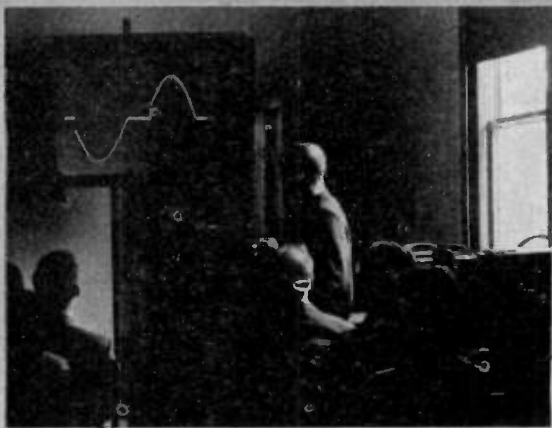
GRAND CENTRAL PALACE

New York, N.Y.

March 3-6, 1947

INDEX AND DISPLAY ADVERTISERS

DISPLAY ADVERTISERS



When projection lenses are available, you can project the oscillogram in a *well-lighted* room with *perfect* visibility, as in this unretouched photograph. Note open window.

PHOTOGRAPHS, PROJECTIONS, HIGH-SPEED TRANSIENTS ARE

Clear

if it's a

DU MONT Type 247-A CATHODE-RAY OSCILLOGRAPH

Modified from the Type 247, this new Du Mont Type 247-A is such a startling success that phenomena hitherto totally invisible can now be *easily* seen. Such modification extends the range of the instrument tremendously in the field of transient studies or high-speed photographic applications.

The modification utilizes the new Type 5RP Cathode-Ray Tube operable at voltages up to 30 KV, producing sufficient brilliance for direct projection, if required.

Other features are: automatic beam blanking; choice of single or continuous sweep; sweep rates available from .5 cps to 50,000 cps; Z-axis amplifier with choice of output polarity; soundly engineered electrical and mechanical design.

Further details on request.

DUMONT *Precision Electronics & Television*

ALLEN B. DUMONT LABORATORIES, INC., PASSAIC, NEW JERSEY • CABLE ADDRESS: ALBEEDU, PASSAIC, N. J., U. S. A.

RCA Victor "Eye Witness" television receiver shown above, gives you 52 square inches of picture brilliance.

A referee's eye view of every play – by Television!

You feel as though you were right there at the game—when you see it through RCA's brilliant television.

Football fans as far as 250 miles away from the stadium have enjoyed watching many of the big games this fall through NBC telecasts. And football fans become television fans when they see how closely the camera follows the ball.

At the game, the sensitive RCA Image Orthicon television camera sees every line plunge, kick, pass and run. It may be a cloudy day or the sun may go down but you still enjoy the *bright sharpness* of the RCA Image Orthicon camera.

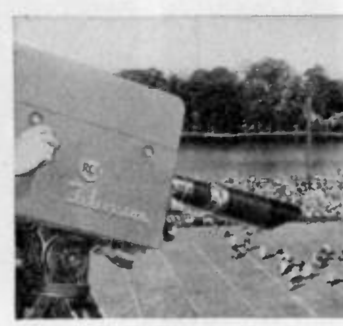
On the screen of your RCA Victor home television receiver none of that bright sharpness is lost.

For after you've tuned in the game, the new RCA Victor "Eye Witness" Picture Synchronizer automatically "locks" the picture in tune with the sending station—eliminates any distortion—assures you of *clearer, steadier* pictures.

For television at its best, as pioneered at RCA Laboratories, you'll want the receiver that features the most famous name in television today—RCA Victor.

• • •

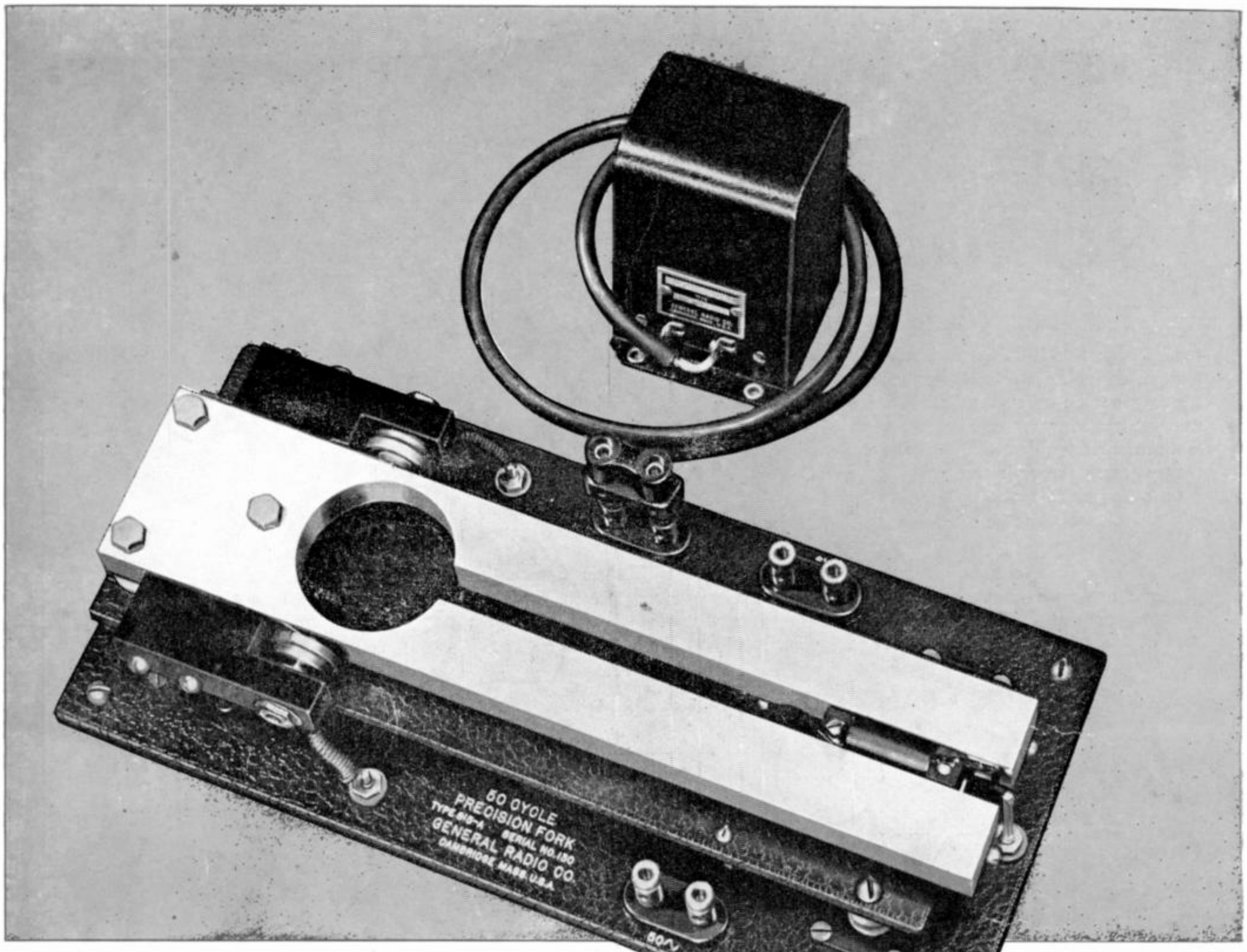
Radio Corporation of America, RCA Building, Radio City, New York 20, N. Y.



RCA Image Orthicon television camera—developed at RCA Laboratories—makes close-ups out of long shots. It enables television to go anywhere by freeing it from the need for strong lights or sunshine.

RCA

RADIO CORPORATION of AMERICA



Ten Parts Per Million

. . . . and a few in stock!

Where the ultra refinement of temperature control is not required, the G-R Type 815 Precision Forks have more than sufficient accuracy for use both in the laboratory and in the field. They are supplied in frequencies of 50, 60 and 100 cycles with a calibration accuracy of ten parts per million. They make excellent low-frequency standards.

Stock for the forks is low-temperature-coefficient stainless steel, received by us in bars. A sample fork is made from each bar and the coefficient of the stock is obtained after a protracted temperature run.

The forks are then machined in our shops. When measured to one millicycle, the unmounted fork is about 2 cycles below its nominal frequency. After this initial measurement, the excess material is milled from the end of the tines and a second frequency check is made. Occasionally the forks must be milled a second time.

Two adjustable loading screws are placed in holes drilled and tapped in the end of each tine. The fork is then assembled and the temperature coefficient of the outer tine screw is obtained. If necessary, excess material is removed from the outer tine screw. The screws are adjusted so that the frequency is within $\pm 0.001\%$ of its nominal value. The voltage coefficient of frequency is obtained; it averages about 0.005%. Output voltage and harmonic content are then measured.

When orders are received the forks are returned to the standardizing laboratory, given a half-hour run and the frequency is measured at a driving voltage of exactly four volts. With each fork a calibration certificate is supplied to show: the frequency to within $\pm 0.001\%$ at a stated temperature between 70 and 80 deg. F.; the temperature and voltage coefficients of frequency.

TYPE 815-A	50-CYCLE FORK	$175.00
TYPE 815-B	60-CYCLE FORK	185.00
TYPE 815-C	100-CYCLE FORK	185.00
TYPE 815-P1	Transformer (for use between the fork and relatively high-impedance loads)	6.95

AT THE MOMENT WE HAVE A SMALL STOCK OF THESE FORKS

GENERAL RADIO COMPANY Cambridge 39, Massachusetts

90 West St., New York 6 — 920 S. Michigan Ave., Chicago 5 — 950 N. Highland Ave., Los Angeles 38