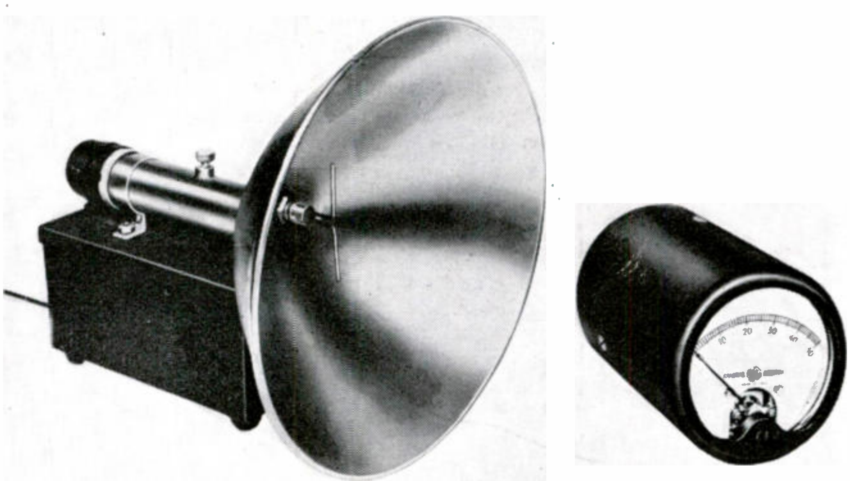
PROCEEDINGS OF THE I·R·E

AND

WAVES AND ELECTRONS

1947
I.R.E. NATIONAL CONVENTION
IN NEW YORK
March 3, 4, 5, 6 and 7



General Electric Company

HERTZIAN EXPERIMENTS MODERNIZED

Schools will demonstrate electromagretic-wave phenomena by means of an oscillator-radiator and an indicating receiver.

November, 1946

Volume 34 Number 11

PROCEEDINGS OF THE I.R.E.

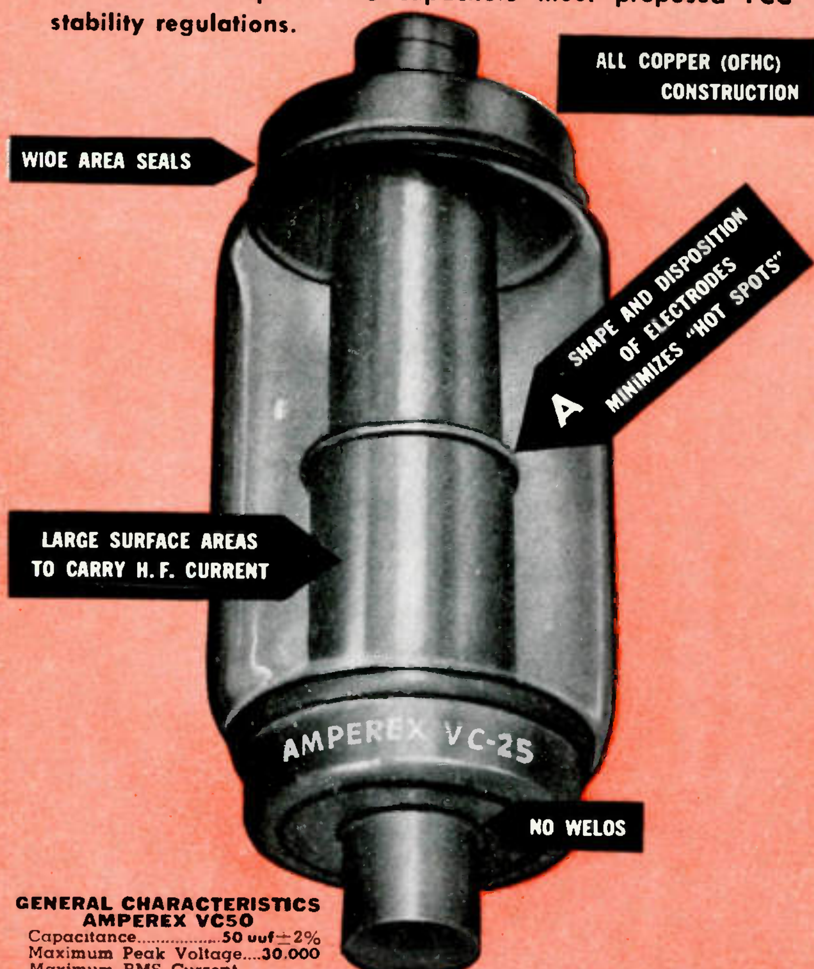
Waves and Electrons Section

The Institute of Radio Engineers

A LONG AND STABLE LIFE...

Design and Production Developments Exclusive with Amperex Set New Stability and Performance Standards for Vacuum Condensers

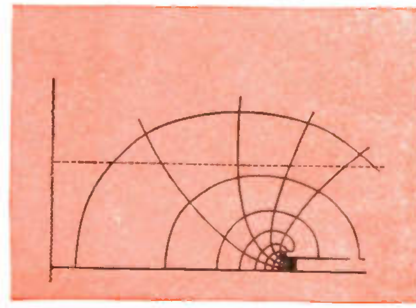
Released six months ago, the new Amperex VC50 and VC25 vacuum condensers have proved themselves a real contribution in communication, dialectric heating and electro-medical apparatus. Their higher current handling ability and lower I^2R losses in reduced space suggest important simplifications in equipment design. Oscillators using Amperex-developed circuits and Amperex VC capacitors meet proposed FCC stability regulations.



GENERAL CHARACTERISTICS
AMPEREX VC50

Capacitance..................50 uuf ± 2%
Maximum Peak Voltage....30,000
Maximum RMS Current
65 Amps at 10 Mc.
40 Amps at 60 Mc.
Dimensions:
6½" ± 3/32" x 2½" Max.

WRITE FOR
COMPLETE TECHNICAL RATING AND DATA SHEETS



Type of equipotential and electrostatic flux lines established by probing electrolytic bath to determine shapes and disposition of electrodes. (POINT "A" IN PHOTOGRAPH)

NEW TECHNIQUES: Design and manufacturing techniques evolved for high power copper anode tubes were successfully brought to bear in developing the unusual qualities of Amperex VC50 and VC25 vacuum condensers. Unique all-copper OFHC construction, large area seals, unusual mechanical ruggedness and elimination of welds insure more efficient and economical operation.

PRIOR ART: When the vacuum condenser project was initiated in the Amperex laboratory, one of the first steps was the prolonged testing of all available types under field conditions. Concentrated high frequency fields and bottlenecks to current passage were common to all. These "hot spots" inevitably resulted in overheating, creating the risks of puncturing and distortion of the delicate balance of elements.

THE SHAPE OF THINGS: More than 200 theoretical shapes for the VC50 electrodes were tested in the electrolytic bath. Resulting lines-of-force curves dictated the shapes finally adopted. These spread the fields of force, eliminating destructive concentrations. It was discovered, also, that elements carrying high frequency current had to offer surface areas much larger than those which had contented older practice. Wires even of comparatively large diameter were found electrically insufficient and in addition, presented mechanical hazards. Elimination of current-carrying welds was indicated. Basic developments and numerous manufacturing refinements growing out of these tests were built into the Amperex VC series. They are responsible for outstanding performance records.

AMPEREX ELECTRONIC CORPORATION

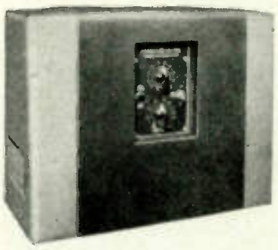
25 WASHINGTON STREET, BROOKLYN 1, NEW YORK

IN CANADA AND NEWFOUNDLAND: ROGERS MAJESTIC LIMITED
11-19 BRENTCLIFFE RD., LEASIDE, TORONTO 12, ONTARIO, CANADA

PROCEEDINGS OF THE I.R.E. AND WAVES AND ELECTRONS, November, 1946, Vol. 34, No. 11. Published monthly in two sections by The Institute of Radio Engineers, Inc., at 330 West 42nd Street, New York 18, N.Y. Price $1.00 per copy. Subscriptions: United States and Canada, $10.00 a year; foreign countries $11.00 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 32A

ELECTRONICS Designers



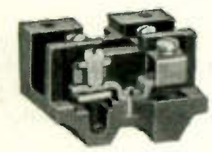
ACCURATE TIME AND CURRENT CONTROL *for bench welders*

To cut welding time on small-part fabrication, such as welding solid or stranded conductors to terminals, welding electronic tube elements, or other small parts, look into the possibilities of the Thyratron-controlled bench-or-tong, low-capacity spot welder.

These alert, accurate controls, with a suitable transformer, have recorded a two-to-one advantage over soldering and rivet fabrication. Because of Thyratron welding controls' accuracy and split-cycle response, rejects drop to a new low. They are designed for either 230v or 460v, 60-cycle operation, and are rated 77 amperes peak on a duty cycle not exceeding 10 per cent. Equipment for 50-cycle operation is also available. Write for Bulletin GEA-4175A.

ONE AND A HALF INCHES *of instrument accuracy*

General Electric's 1½-inch panel instruments include direct-current, radio-frequency, and audio-frequency types, in both conventional and watertight construction. All feature the compact, internal-pivot element and Textolite cases; will withstand 50 G's shock, and are accurate to within ±2 per cent. The conventional, direct-current instrument is supplied self-contained for current measurements from 100 microamperes to 10 amperes and for voltage measurements up to 150 volts. For other requirements, combinations of instruments and accessories can be had. Write for Bulletin GEA-4380.

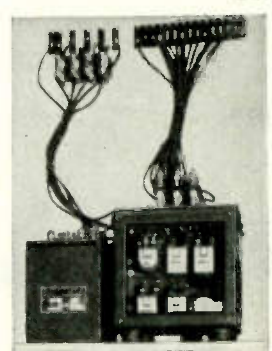


TERMINAL BOARDS *to cut wiring time*

There's less motion and more wiring speed when terminal boards are G-E Type EB-2. Strip the wire-end, insert it in the connector, tighten a screw, and the connection is made. Each of these solderless, pressure connectors will accommodate one No. 8 stranded conductor, two No. 12 stranded conductors, or three No. 12 solid conductors, all AWG.

Type EB-1 differs from EB-2 only in its terminals, which are the conventional washer-headed screw type. Both boards are molded from strong, long-lasting Textolite, both are available in 4-, 6-, 8-, and 12-pole sizes, and are equipped with marking strips. Covers are optional. Write for Bulletin GEA-1497A.

Fast Hook-ups that stay put with FLAMENOL WIRE

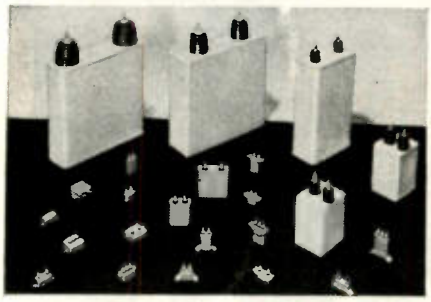


Flamenol hook-up wire's tough, plasticized-polyvinyl-chloride insulation strips clean, bends without cracking, and is available in seven different colors. Normally, it needs no bulky armor-braid for protection. As a result, Flamenol speeds up wiring operations on electronic apparatus, where voltages do not exceed 600. Flame-resistant, corrosion-resistant, non-oxidizing, and unaffected by most hydrocarbon solvents, mild acids and alkalies, Flamenol rarely needs either attention or replacing. Its glossy finish looks new, and stays that way. Write for Bulletin GEA-4352.

GENERAL ELECTRIC

Digest

TIMELY HIGHLIGHTS ON G-E COMPONENTS



NEW D-C PYRANOL* CAPACITORS

with new quality, sizes, ratings

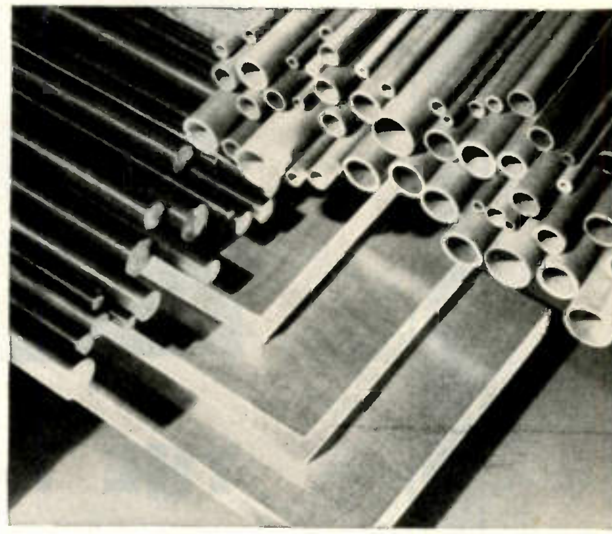
New materials, new manufacturing techniques and strict quality control, which were so important in the excellent records d-c Pyranol capacitors made during the war, are now incorporated into a new line of d-c Pyranol capacitors built to meet exacting commercial requirements.

This new line of d-c Pyranol capacitors has a broader range of sizes, ratings, and mounting arrangements, with characteristics that allow operation through the temperature range from –55C up to 85C, at altitudes as high as 7,500 feet. Sizes range from "bathtub" up to large, welded-steel case sizes, capacitance from .01 muf to 100 muf, and voltages from 100v to 100,000v. Write *Transformer Division, General Electric Company, Pittsfield, Mass.*

*Reg. U. S. Pat. Off.

MORE "KNOW" MEANS *better "do"!*

To help train new technical personnel, and make supervisory and production men's jobs mean more, G.E. offers this 12 part talking slide film, prepared to teach even non-technical personnel the elements of electronics. It comes complete with 12 slide films and records, 300 review books, instructor's manual and carrying case; price of the kit is $100. Call your local G-E office, or order direct from *Apparatus Dept., Sect. 642-13, General Electric Co., Schenectady 5, N. Y.*



FITS AND FIT FOR

any laminated-plastic job

Because it can be fabricated with machine tools into practically unlimited numbers of shapes, G-E Textolite sheet, tube, and rod stock adds flexibility to electronic apparatus design. Over fifty different grades – each with an individual combination of electrical, mechanical, chemical, and thermal properties – assures you that tube bases, coil forms, bus-bar supports and other components will be exactly right for your job. For additional information on G-E Textolite, write to *Plastics Divisions, Chemical Department, General Electric Company, Pittsfield, Mass*

General Electric Company, Sect. 642-13
Apparatus Department, Schenectady 5, N. Y.

Please send me

- ....GEA-1497A (Terminal Boards)
- ....GEA-4175A (Thyratron Welding Controls)
- ....GEA-4380 (Small Panel Instruments)
- ....GEA-4352 (Flamenol)

Note: More data available in Sweets File for product designers.

Name______________________________

Company___________________________

Address____________________________

City__________________State_________

. . . Impromptu Discussions about Miniature Tubes

"It's a fact, John, those little TUNG-SOL Miniatures are actually doing a better job than the big tubes. Take radio frequency amplifiers for example. There's the TUNG-SOL 6BA6 for transformer and storage battery operated sets and the 12BA6 for series filament operation. It's only natural that you get greater rigidity with the shorter structure and the same grid cathode spacing . . . and to give you some idea of space saving, one of these little fellows occupies less than half the chassis area that a big tube requires. Think what this means in compact equipment like an auto set.

"With these miniature amplifiers it's possible to obtain the correct bias by means of a cathode resistor of 68 ohms for normal operating current. If unbypassed this gives partial compensation for variations in input capacitance due to changes in automatic volume control voltage. Almost complete compensation can be obtained with a 100 ohm unbypassed cathode resistor. Under this condition the effective transconductance is 2700 microhms. Excellent performance is obtained in the frequency modulation and television intermediate frequency bands. The stable gain figure of merit is about the same as for the large type tube while the broad band figure of merit is about 30% greater.

"I tell you, John, you should lay your tube problems before these TUNG-SOL Engineers. They'll help you select the miniature that'll be most efficient and they won't disclose your plans to others. You see they're tube manufacturers, not set builders."

TUNG-SOL

vibration-tested

ELECTRON TUBES

TUNG-SOL LAMP WORKS INC., NEWARK 4, NEW JERSEY

Sales Offices: Atlanta • Chicago • Dallas • Denver • Detroit • Los Angeles • New York

Also Manufacturers of Miniature Incandescent Lamps, All-Glass Sealed Beam Headlight Lamps and Current Intermittors

Typical discharge application—the "Syncroflash"—AC operated light-weight 100-watt-second high-speed photo-flash apparatus.

Maximum Storage Capacity per Ounce and Cubic Inch...

AEROVOX SERIES PX *Energy-Storage* CAPACITORS

The logical choice for...

HIGH-SPEED FLASH PHOTOGRAPHY
CAPACITOR-DISCHARGE WELDING
ELECTRONIC TIMING CIRCUITS, ETC.

12.5 mfd. 4000 volt DC peak Hyvol Energy-Storage Capacitor.

ENERGY STORAGE* CAPACITORS
PREFERRED RATINGS

WATTS—SECONDS	VOLTS—E	TYPE NO.	DIMENSIONS HT.	WT. LBS.
22.5	1.5 KVDC peak	PX10F1	2½ x 3¾ x 4⅝	2¾
50	1.8 " "	PX13D1	4-9/16 x 3¾ x 4⅝	4⅜
50	2.0 " "	PX14D2	4-9/16 x 3¾ x 4⅝	4⅜
100	2.5 " "	PX15D1	4-9/16 x 3¾ x 6½	6⅛
75	3.0 " "	PX18D1	4-9/16 x 3¾ x 4⅝	4⅜
550	3.0 " "	PX22F1	5⅛ x 13½ x 13	App. 64
100	4.0 " "	PX20D1	4-9/16 x 3¾ x 4⅝	4⅜
500	4.0 " "	PX32F1	5⅛ x 13½ x 13	63

Stored Energy = ½ CE² Watts-Seconds (C in farads)

● Interested in storing a large amount of energy in a small space—and at low cost, first and last?

If so, Aerovox Series PX Energy-Storage Capacitors are your logical choice. Here's why:

Light. Fast discharge. Easily installed. Exceptionally rugged mechanically and electrically. Time-proven Hyvol impregnant and fill for the generously-proportioned paper-and-foil sections, insures dependable service and longest life. Positively the maximum energy-storage with minimum bulk and weight.

Preferred ratings available for prompt delivery, are listed at left. Other ratings can be designed and made to order for exceptional requirements.

● Our engineers will gladly discuss the advantages of Aerovox Energy-Storage Capacitors as applied to your specific problems or needs.

AEROVOX capacitors

FOR RADIO-ELECTRONIC AND INDUSTRIAL APPLICATIONS

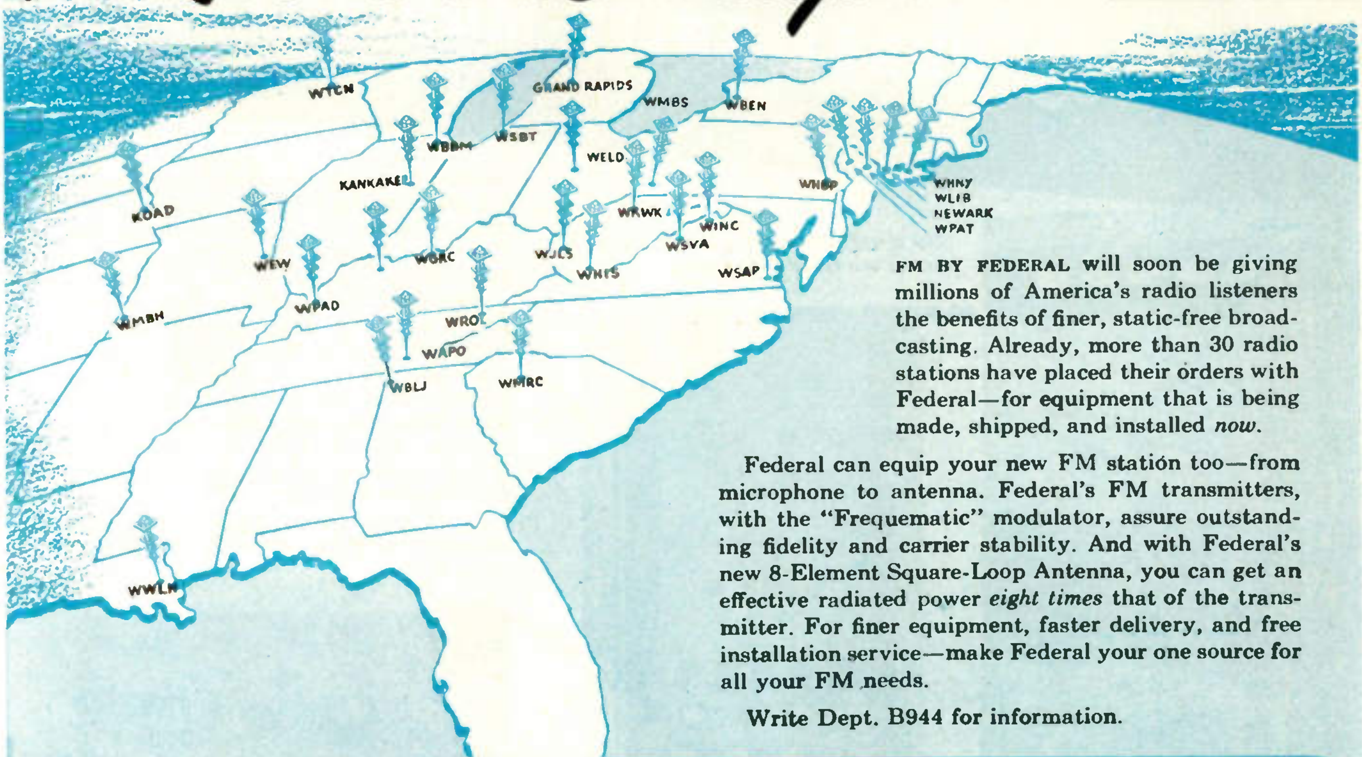
AEROVOX CORPORATION, NEW BEDFORD, MASS., U.S.A.

SALES OFFICES IN ALL PRINCIPAL CITIES • Export: 13 E. 40th St., New York 16, N. Y.

Cable: 'ARLAB' • In Canada: AEROVOX CANADA LTD., HAMILTON, ONT.

Federal is really putting FM on the map!

MORE THAN 30 BONA FIDE ORDERS ALREADY SIGNED!



FM BY FEDERAL will soon be giving millions of America's radio listeners the benefits of finer, static-free broadcasting. Already, more than 30 radio stations have placed their orders with Federal—for equipment that is being made, shipped, and installed *now*.

Federal can equip your new FM station too—from microphone to antenna. Federal's FM transmitters, with the "Frequematic" modulator, assure outstanding fidelity and carrier stability. And with Federal's new 8-Element Square-Loop Antenna, you can get an effective radiated power *eight times* that of the transmitter. For finer equipment, faster delivery, and free installation service—make Federal your one source for all your FM needs.

Write Dept. B944 for information.

Here Are The First 30 Orders for FM by Federal

WSVA	Harrisonburg, Va. 10-Kw Transmitter 5-Kw Transmitter Associated Equip.
WPAT	Paterson, N. J. 10-Kw Transmitter
WGRC	Louisville, Ky. 10-Kw Transmitter
WMBH	Joplin, Missouri 3-Kw Transmitter
WBEN	Buffalo, New York 3-Kw Transmitter 2-Element Square-Loop Antenna Associated Equip.
WMRC	Greenville, S. C. 10-Kw Transmitter 8-Element Square-Loop Antenna Associated Equip.
WHBP	Reading, Pa. 3-Kw Transmitter Associated Equip.
WHNY	Hempstead, N. Y. 1-Kw Transmitter
WINC	Winchester, Va. 3-Kw Transmitter 6-Element Square-Loop Antenna
WLIB	Brooklyn, New York 10-Kw Transmitter Antenna Associated Equip.
WBLJ	Dalton, Georgia 3-Kw Transmitter Associated Equip.
WELD	Columbus, Ohio 10-Kw Transmitter Antenna Associated Equip.
KOAD	Omaha, Nebraska 1-Kw Transmitter 8-Element Square-Loop Antenna Associated Equip.
WEW	St. Louis, Missouri 10-Kw Transmitter 8-Element Square-Loop Antenna Associated Equip.
WSAP	Portsmouth, Va. 3-Kw Transmitter Associated Equip.
WTCN	Minneapolis, Minn. 3-Kw Transmitter 8-Element Square-Loop Antenna Associated Equip.
WWLH	New Orleans, La. 3-Kw Transmitter Antenna Associated Equip.
WAPO	Chattanooga, Tenn. 250-Watt Transmit.
WROL	Knoxville, Tenn. 8-Element Square-Loop Antenna Associated Equip.
WBBM	Chicago, Illinois 3-Kw RF Amplifier
WKWK	Wheeling, W. Va. 3-Kw Transmitter Associated Equip.
WPAD	Paducah, Kentucky 3-Kw Transmitter Associated Equip.
WMBS	Uniontown, Pa. 1-Kw Transmitter Associated Equip.
WSBT	South Bend, Indiana 10-Kw Transmitter 8-Element Square-Loop Antenna Associated Equip.
WHIS	Bluefield, W. Va. 20-Kw Transmitter 12-Element Square-Loop Antenna
WCIL	Carbondale, Ill. 1-Kw Transmitter Associated Equip.
WJLS	Beckley, W. Va. 3-Kw Transmitter 8-Element Square-Loop Antenna Associated Equip.
#	North Jersey Radio, Inc. Newark, New Jersey 3-Kw Transmitter Antenna Associated Equip.
#	Grand Rapids, Mich. 3-Kw Transmitter Associated Equip.
#	Kankakee, Illinois 10-Kw Transmitter Associated Equip.

#Call letters not yet assigned.

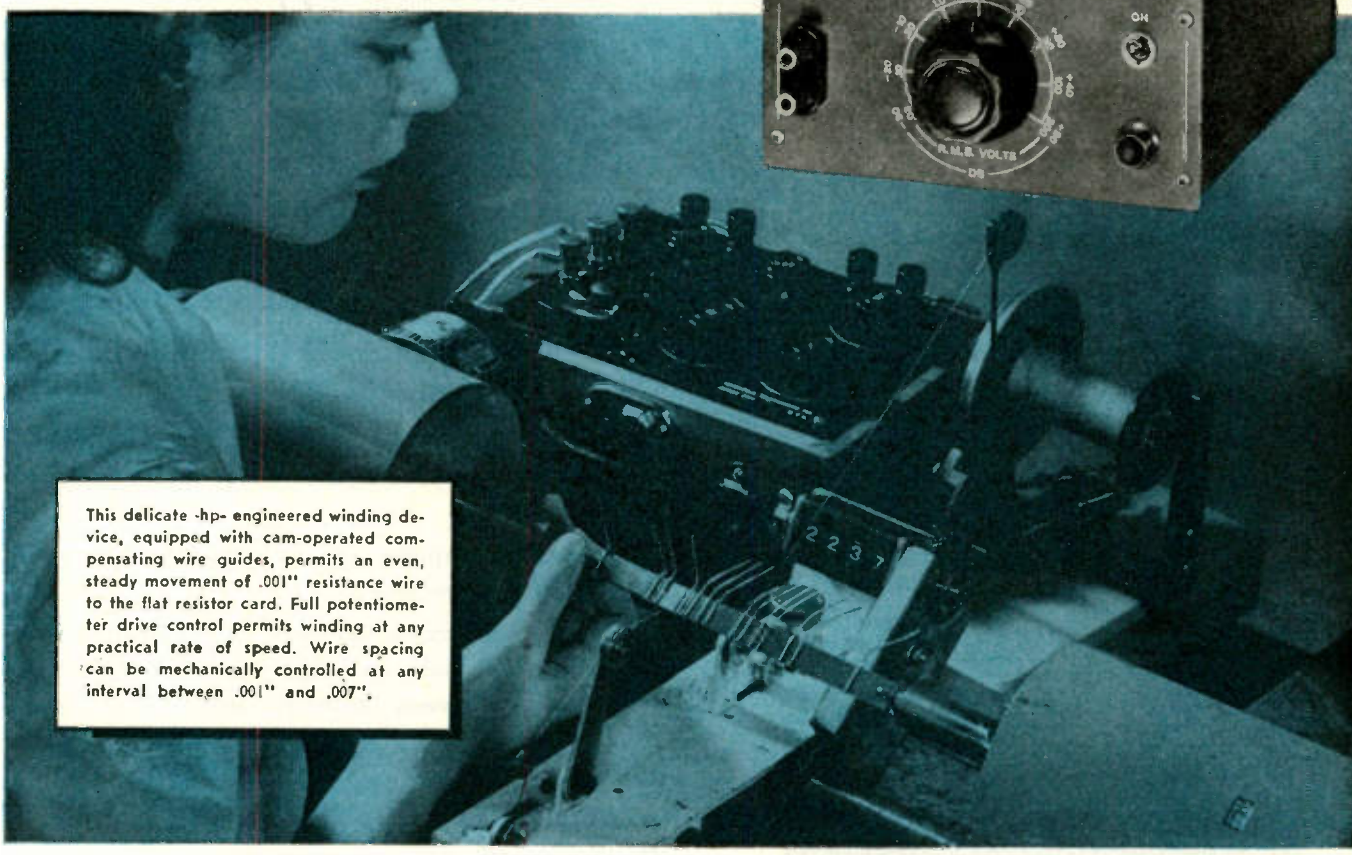
Federal Telephone and Radio Corporation

In Canada:—Federal Electric Manufacturing Company, Ltd., Montreal.
Export Distributors:—International Standard Electric Corp. 67 Broad St., N.Y.C.

AN IT&T ASSOCIATE

Newark 1, New Jersey

Dependability and Uniformity of Accuracy Assured in the -*hp*- 400A Vacuum Tube Voltmeter



This delicate -hp- engineered winding device, equipped with cam-operated compensating wire guides, permits an even, steady movement of .001" resistance wire to the flat resistor card. Full potentiometer drive control permits winding at any practical rate of speed. Wire spacing can be mechanically controlled at any interval between .001" and .007".

Flat resistor voltage dividers for the -*hp*- 400A Voltmeter are precision-wound by machine. This development by -*hp*- engineers makes possible the construction of more precisely uniform instruments —more economically, more quickly.

The -*hp*- 400A Voltmeter long ago set a high standard of accuracy in measurements ranging from .005 volts to 300 volts, at frequencies from 10 cps to 1 megacycle. There are no troublesome adjustments to make during measurement, and normally no special precautions against overloads are needed.

The meter of the -*hp*- 400A has scales for both voltage and decibel calibrations; and a handy range knob permits instantaneous range selection in 10 db steps. The instrument itself is light, rugged, and compact for easy portability.

Write today for complete details and price of this precision-built, general purpose voltmeter.

HEWLETT-PACKARD COMPANY
1293D PAGE MILL ROAD, PALO ALTO, CALIFORNIA

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

LABORATORY INSTRUMENTS FOR SPEED AND ACCURACY

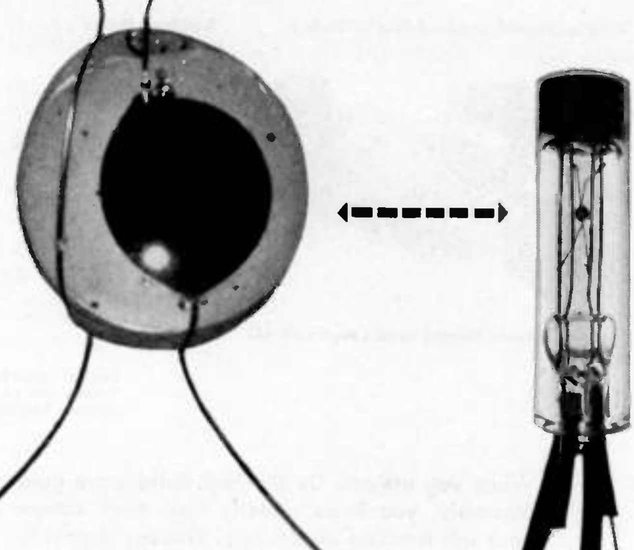
The Eye That Never Closes

You are looking at a thermistor — a speck of metallic oxide imbedded in a glass bead hardly larger than a pinhead and mounted in a vacuum. The thermistor was developed by Bell Telephone Laboratories to keep an eye on the amplification in long-distance telephone circuits.

When a thermistor is heated, its resistance to electric current changes rapidly. That is its secret. Connected in the output of repeater amplifiers, it heats up as power increases, cools as power decreases. This change in temperature alters the resistance, in turn alters the amplification, and so maintains the desired power level. Current through the wire at the left provides a little heat to compensate for local temperature changes.

Wartime need brought a new use for this device which can detect temperature changes of one-millionth of a degree. Bell Laboratories scientists produced a thermistor which could "see" the warmth of a man's body a quarter of a mile away.

Thermistors are made by Western Electric Company, manufacturing branch of the Bell System. Fundamental work on this tiny device still continues as part of the Laboratories program to keep giving America the finest telephone service in the world.



BELL TELEPHONE LABORATORIES

EXPLORING AND INVENTING, DEVISING AND PERFECTING FOR CONTINUED IMPROVEMENTS AND ECONOMIES IN TELEPHONE SERVICE

INFINITELY LONGER LIFE FOR FLUORESCENT LAMP CAPACITORS...

thanks to SPRAGUE VITAMIN Q

(REG. U. S. PAT. OFF.)

Greatly increased production facilities now permit the application of Sprague's famous Vitamin Q impregnant to ballast capacitors for fluorescent lamps—with truly outstanding results. The tables below tell the story—on severe tests that leave nothing open to question as to the remarkable superiority of these Sprague units. *NO Sprague Vitamin Q Capacitors failed during the life of the tests. ALL of the competing units did!*

SPRAGUE ELECTRIC COMPANY, North Adams, Mass.

LIFE TEST NO. 1

Tested at 490v. A.C. 85°C. in circulating air

No. Units Tested	Maker	Hours Life at Failure of each unit tested 1st	2nd	3rd	4th	5th	Impregnant
5	SPRAGUE	NO FAILURES AFTER 750 HOURS!					VITAMIN Q
5	Mfr. 1	37	124	339	498	516	Chlorinated diphenyl
2	Mfr. 2	107	243	—	—	—	Mineral Oil

POWER FACTOR

550 v. A.C. 85°C.

(as measured on a Schering bridge)

Sprague 0.27%
Mfr. 1 .... 0.62%
Mfr. 2 .... 0.45%

LIFE TEST NO. 2

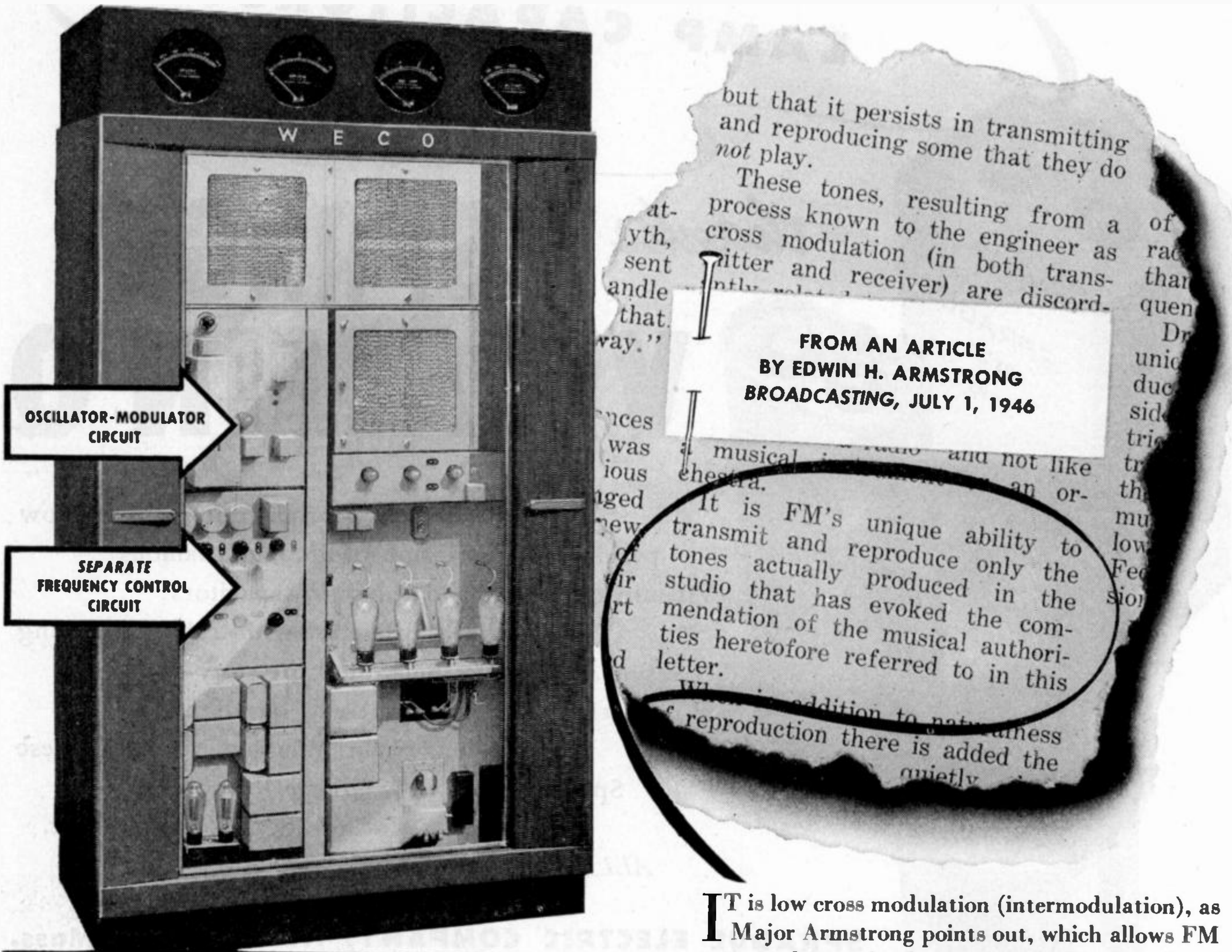
Tested at 575v. A.C. 85°C. in still air

No. Units Tested	Maker	Results	Impregnant
4	SPRAGUE	NO FAILURES AFTER 750 HOURS!	VITAMIN Q
3	Mfr. 1	All failed in less than 4 hours	Chlorinated diphenyl
3	Mfr. 2	" " " " " 4 "	Mineral Oil
3	Mfr. 3	" " " " " 4 "	Mineral Oil

Units tested in both cases were standard 3½ mfd. 330v. A.C. Fluorescent Capacitors in 2" d. x 2¼" h. cans.

Important FM news

for Broadcast Managers . . . Engineers . . . Listeners



IT is low cross modulation (intermodulation), as Major Armstrong points out, which allows FM to reproduce only the notes actually played and thus achieve such naturalness of tone.

Western Electric's Synchronized FM transmitters are unique in FM broadcasting because of their *unusually low intermodulation products*—achieved by a complete separation of the oscillator-modulator circuit from the frequency control circuit.

For other important features of Western Electric's complete new line of FM transmitters, contact your nearest Graybar Broadcast Equipment Representative, or write to Graybar Electric Company, 420 Lexington Avenue, New York 17, N.Y.

Unexcelled Performance of Western Electric FM Transmitters

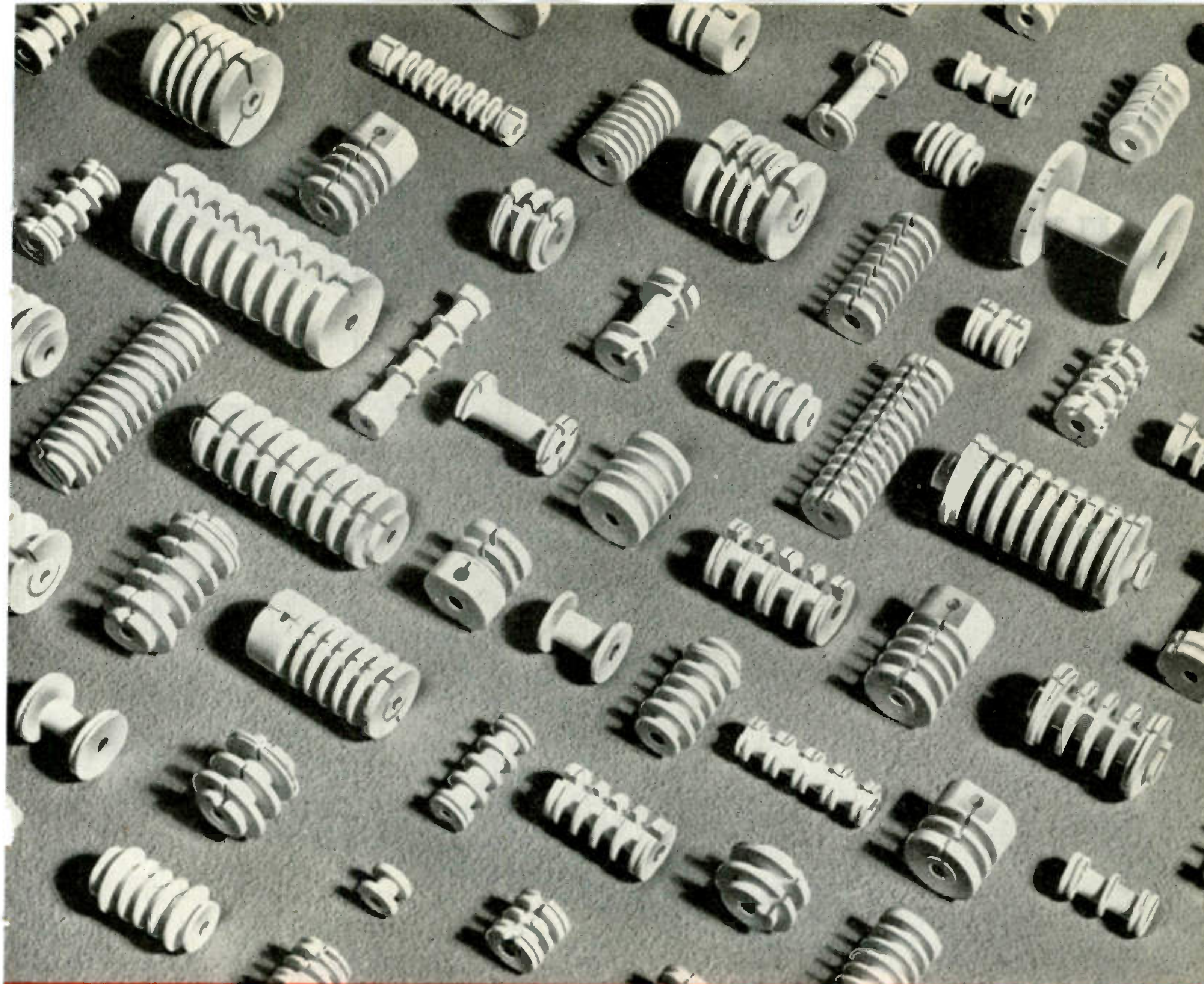
Audio Frequency Response	±0.25 DB from 30 to 15,000 cycles
Harmonic distortion — for ±75 KC swing	Less than 0.5% from 30 to 15,000 cycles
— for ±100 KC swing	Less than 0.75% from 30 to 15,000 cycles
Intermodulation — — for ±75 KC swing	*Less than 0.5% for 80% 50 cycles and 20% 1000 cycles; less than 1.0% for 80% 50 cycles and 20% 7000 cycles*
FM noise level	65 DB below ±75 KC swing
AM noise level	50 DB below 100% amplitude modulation
Carrier Frequency stability	Less than 2000 cycles deviation (no crystal heater)

Western Electric

— QUALITY COUNTS —

Western Electric

Distributed by Graybar
OFFICES IN 90 PRINCIPAL CITIES



MAKING TUBES *is easy* *If you know how!*

Edwin F. Dillaby (designer of the popular HY75) develops the mount structure for a new transmitting triode.

TUBE DESIGN is a *BALANCING ACT*

The job of a vacuum tube designer would really make you tear your hair. Drawing mainly on long experience — only the bare principles of tube design are found in books — the design engineer must co-ordinate the innumerable interlocking characteristics you specify.

Using standard parts when possible — hand-fabricating others, he assembles and processes engineering samples. Some characteristics may fall outside limits. Then begins a seesaw of compromises. Screen diameter is lowered; input capacitance rises. Plate current is raised; amplification factor drops. Back and forth teeters the design. Interlocking electrical, mechanical, physiochemical, ceramic, and metallurgical characteristics must be reconciled one after another. Finally the harassed designer submits apparently satisfactory tubes for application tests.

You guessed it. Changes are required. The balancing act begins anew. Innumerable variables are again co-ordinated. Science and creative craftsmanship triumph; everyone is satisfied. Production takes over. Sure, it's a swell tube. But could this lead be changed, this spacer eliminated, this material substituted? Well, you see what we mean.

Through the years, Hytron design engineers have sweated for you. They have originated: GT, subminiature, vhf, instant-heating tubes. They have improved standard types including: OC3, OD3, 1616. Their experience will continue to craft for you the best in tubes.

SPECIALISTS IN RADIO RECEIVING TUBES SINCE 1921

HYTRON

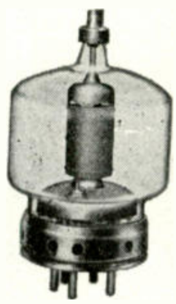
RADIO AND ELECTRONICS CORP.

MAIN OFFICE: SALEM, MASSACHUSETTS

Eimac TUBES THE COUNTERSIGN OF DEPENDABILITY IN ANY ELECTRONIC PRODUCT

Eimac Tetrodes lead the way to simplified CRYSTAL FREQUENCY CONTROL FOR DIATHERMY *and* ELECTRONIC HEATING

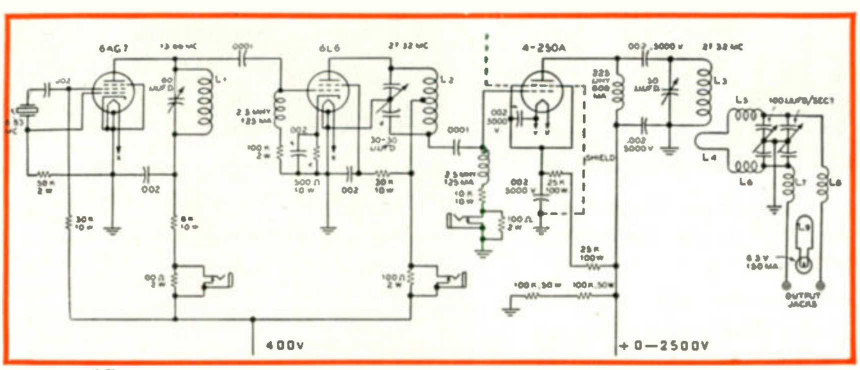
Crystal control of frequency now becomes the practical answer to the new frequency stability requirements. Eimac tetrodes make crystal frequency control feasible and simple. *Crystal control through Eimac tetrodes means maximum frequency stability, end of objectionable radiation, and handy portability for electronic heating units of the future.*



Eimac 4-250A Tetrode

Here's How an Eimac Tube Makes This Practical

The way just one Eimac 4-250A tetrode makes crystal frequency control practical is shown in this *operative,* experimental circuit assembled by Eimac engineers. The circuit is also applicable to other forms of electronic heating.



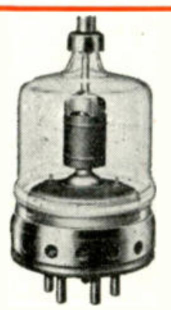
Greater Stability...Longer Life

Both tetrodes have specially treated elements that insure longer life. Both have non-emitting grids which give great operating stability.

Because of their low grid-plate capacitance (0.12 uufd in the 4-250A and 0.05 uufd in the 4-125A), these tubes normally require no neutralization at diathermy or heating frequencies. (In fact, the 4-250A normally requires no neutralization up to 70 Mc; 4-125A ordinarily needs none even at 120 Mc.)

Eimac Tetrodes for Power Amplification Throughout the Useful Frequencies

Dependable, durable Eimac tetrodes are admirably suited for diathermy or electronic heating work, or for almost any power amplification assignment at any frequency, including VHF. Write today to Eimac's local representatives or factory engineers for complete data on these tubes.



Eimac 4-125 Tetrode

Here's Why Eimac Tubes Make Crystal Frequency Control Practical

Because of their unique characteristics, Eimac power tetrodes such as the 4-250A and 4-125A are ideal for use in circuits like the one above.

These tubes have an unusually high power-gain for efficient performance at medium, high, or the very high frequencies used in diathermy and heating. For example, the 4-250A (at frequencies up to 70 Mc.) develops power output of 750 watts with a driving power of less than 5 watts. The 4-125A tetrode delivers 375 watts output with less than 3 watts drive.

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SYLVANIA NEWS

CIRCUIT ENGINEERING EDITION

NOV. *Prepared by* SYLVANIA ELECTRIC PRODUCTS INC., Emporium, Pa. 1946

SYLVANIA COMMERCIAL ENGINEERING DIVISION AIDS IN PRODUCING EFFICIENT SET CIRCUITS

Views of Sylvania Electric's renowned Commercial Engineering Department. Here, new discoveries from Sylvania's laboratories are built into the latest products.

Helping to engineer the best possible radio circuits for many set manufacturers is one of the numerous achievements of Sylvania's famous Commercial Engineering Department.

Time and again circuits found to be unnecessarily complicated were simplified and made even *more efficient* through the work carried on here.

HELP
SHARE A MEAL EVERY DAY

For nearly twenty years Sylvania's Commercial Engineering Department has contributed to the advancement of circuit design as well as to the development of a great variety of electronic and lighting products.

SOME PRODUCTS OF SYLVANIA ENGINEERING RESEARCH

Radio receiving tubes, such as the famous Lock-In.
Miniature radio receiving tubes, including the tiny T-3.
1.4 volt battery tubes.
150 ma. line of 6.3 volt tubes.
Radio transmitting tubes.
Cathode ray tubes.
Pirani tubes.
Silicon Crystal Diodes.
1N34 and 1N35 Germanium Crystals.
Electroflash Tubes and Units.
Radio tube parts.
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SYLVANIA ELECTRIC

Emporium, Pa.

MAKERS OF RADIO TUBES; CATHODE RAY TUBES; ELECTRONIC DEVICES; FLUORESCENT LAMPS, FIXTURES, WIRING DEVICES; ELECTRIC LIGHT BULBS

Important advantages are yours with JOHNSON *condensers*

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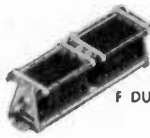
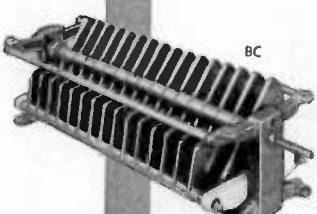


F DUAL

H DUAL

Many evidences of superiority in JOHNSON condensers reflect the twenty-three years of experience that has gone into them. Each type is carefully designed by electronic engineers for maximum circuit efficiency. A primary design objective at JOHNSON'S has been the accomodation of a greater number of specific requirements with a standard condenser or minor modification of a standard. JOHNSON'S search for better design and methods is continuous and employs first class engineering talent and equipment. Many developments, such as the new plate design mentioned below, not only bring increased efficiency but a saving in cost.



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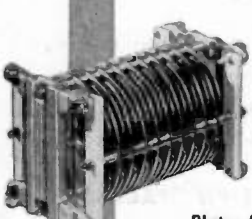
JOHNSON offers many standard types from which to choose with capacities to 10,000 mmf, voltage ratings to 30,000. See your distributor or write to Dept. W today



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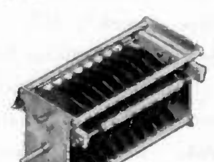
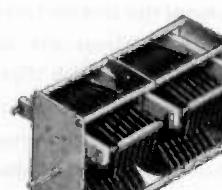


D

Plates for types A and B condensers are of the new heavy rounded edge design recently developed by JOHNSON engineers. Their higher breakdown voltage permits closer spacing, a shorter condenser, lower minimum, and less inductance at U H F. These features combined with new end frame design reduce weight to minimum, yet cost no more, in most cases less because of the saving in material.



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E. F. JOHNSON CO., WASECA, MINNESOTA

Recently released from Army-Navy classification, this equipment, formerly known as the TS-223/AP, is now being produced by Aircraft Radio Corporation as the A.R.C. Test Set, Type H-10.

This highly specialized test equipment is used primarily for the measurement of radar receiver sensitivity, frequency and band width; and transmitter power and frequency, in the 24,000 Mc. band. Other field or laboratory measurements possible with this equipment include testing of type 2K50 r-f oscillator tubes and measurement of radar receiver recovery time.

The heart of the A.R.C. Test Set, the 24,000 Mc. wavemeter and attenuator, is available separately, if desired.

For full information on A.R.C. microwave accessories and component parts, write

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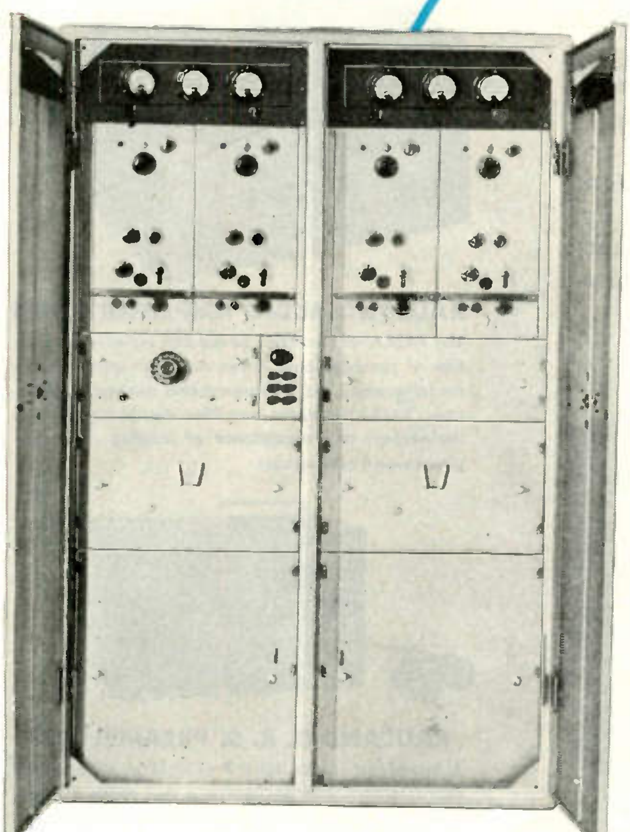

FTR-184 radio transmitter, with (1) LF and (3) HF radio-frequency units, (2) modulators, (2) power supplies, and remote control equipment.

TRANS WORLD AIRLINE has joined the rapidly increasing ranks of famous users of Federal's FTR-184 ground-station transmitters. On these major airlines, radio equipment plays a vital role in maintaining schedules and controlling air traffic—a job where reliability is the watchword.

Federal's radio transmitter 184 is designed and built for just this kind of service—every unit backed by 37 years of research and experience. This compact unit—modern in design, modern in styling—is adaptable to practically all operating requirements. The component parts, such as power supplies, modulators, r-f units and auxiliaries, can be combined to provide the frequencies, emissions and types of operation which will best fill your needs.

For complete information, write today for bulletin A237.

DATA

Frequency Range Power Output, and Type of Emission

(HF) 2 to 20 Mc...... 500 watts, Telephone and Telegraph
(VHF) 108 to 140 Mc... 200 watts, Telephone
(LF) 200 to 540 Kcs.. 400 watts

Frequency Control—Low temperature-coefficient crystals for all operating frequencies. Facilities can be supplied for switching in either of two crystals for adjacent-channel operation.

Frequency Response—300 to 4000 cycles, plus or minus 3 db with reference to response at 1000 cycles.

Distortion—Less than 10% at 95% modulation.

Remote Control—Transmitter on-off, channel selection, push-to-talk, and keying may be performed over telephone circuits by remote control equipment.

Primary Power—220 volts, 50/60 cycles, single phase.

Federal Telephone and Radio Corporation

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Export Distributor:—International Standard Electric Corporation, 67 Broad St., N. Y. C.

An IT&T Associate — FTR Federal Telephone & Radio

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VEST POCKET RADIOS
AIR BORNE DEVICES

UTC SUB-OUNCER SERIES

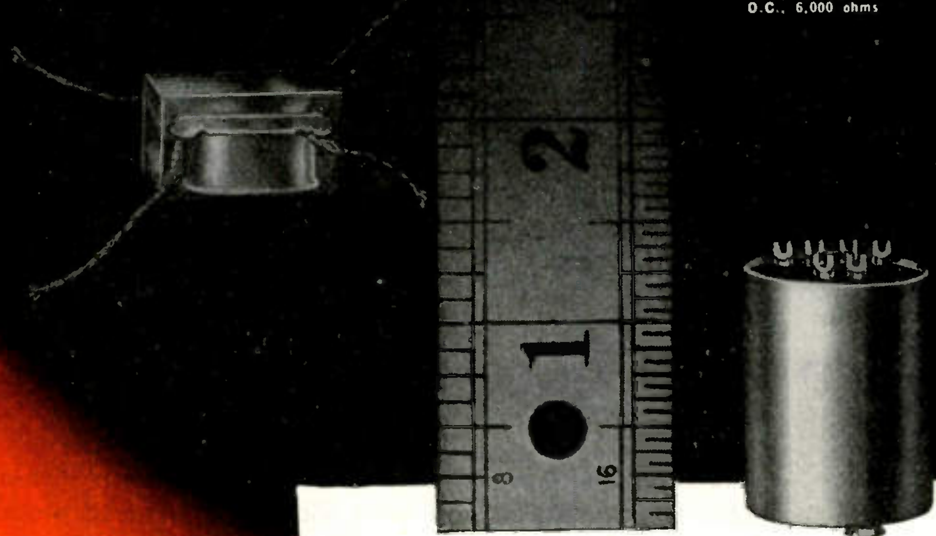
UTC Sub-Ouncer units are 9/16" x 5/8" x 7/8" and weigh only 1/3 ounce. Through unique construction, however, these miniature units have performance and dependability characteristics far superior to any other comparable items. The coil is uniform layer wound of Formex wire . . . On a molded nylon bobbin . . . insulation is of cellulose acetate . . . leads mechanically anchored (no tape) . . . core material Hipermalloy . . . entire unit triple (waterproof) sealed. The frequency response of these standard items is ± 3 DB from 200 to 5,000 cycles.

Type	Application	Level	Pri. Imp.	D.C. in Pri.	Sec. Imp.
SO-1	Input	+ 4 V.U.	200 50	0	250,000 62,500
SO-2	Interstage/3:1	+ 4 V.U.	10,000	0	90,000
SO-3	Plate to Line	+ 23 V.U.	10,000 25,000	3/1.5 mil.	200 500
SO-4	Output	+ 20 V.U.	30,000	1.0 mil.	50
SO-5	Reactor 50 Hy at 1 mil. D.C. 3000 ohms D.C. Res.				

UTC OUNCER SERIES

The standard of the industry for seven years. The overall dimensions are 7/8" diameter by 1-3/16" height including lugs. Mounting is effected by two screws, opposite the terminal board side, spaced 11/16". Weight approximately one ounce. Units not carrying D.C. have high fidelity characteristics being uniform from 40 to 15,000 cycles. Items with D.C. in pri. are for voice frequencies from 150 to 8000 cycles.

Type	Application	Pri. Imp.	Sec. Imp.
O-1	Mike pickup or line to 1 grid	50, 200, 500	50,000
O-4	Single plate to 1 grid	8,000 to 15,000	60,000
O-5	Single plate to 1 grid, D.C. in Pri.	8,000 to 15,000	60,000
O-6	Single plate to 2 grids	8,000 to 15,000	95,000
O-8	Single plate to line	8,000 to 15,000	50, 200, 500
O-9	Single plate to line, D.C. in Pri.	8,000 to 15,000	50, 200, 500
O-12	Mixing and matching	50, 200	50, 200, 500
O-13	Reactor, 200 Hys-no D.C., 50 Hys-2MA D.C., 6,000 ohms		



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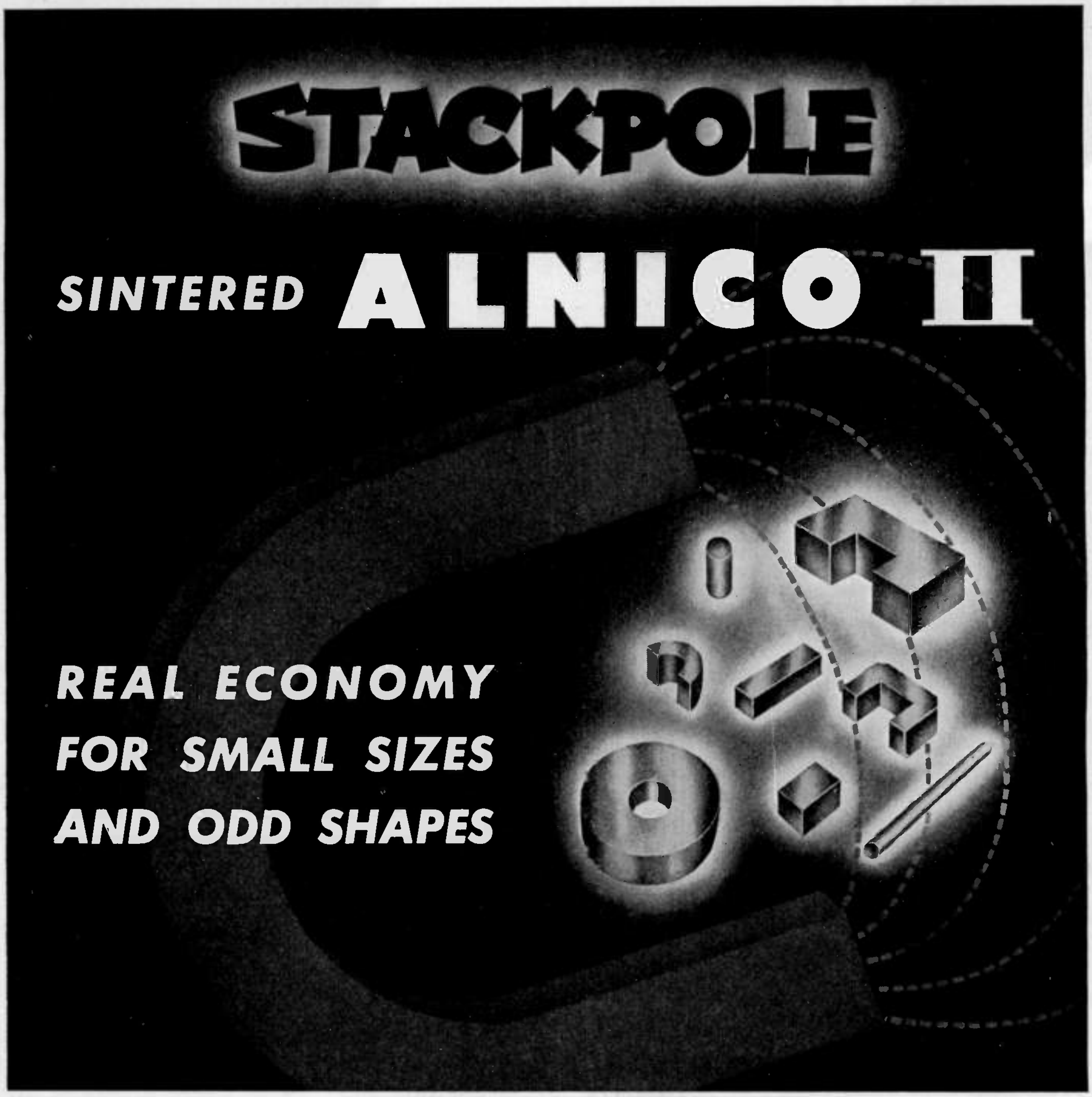
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REAL ECONOMY
FOR SMALL SIZES
AND ODD SHAPES

RCA-1P42

—a tiny high-vacuum phototube with unusual possibilities

FEATURES

- Can be used in closely confined space
- Head-on structure permits close spacing of tubes in banks
- Excellent sensitivity—single amplifier stage is sufficient for many relay services
- Smooth end terminal permits pin-jack mounting
- High-vacuum insures high stability

THE RCA-1P42 high-vacuum phototube opens up entirely new fields of application to the design engineer—particularly for control purposes where space limitation is a prime consideration. Its extremely small size, combined with the unique "head-on" construction, permits exceedingly close spacing of the tubes in banks for controlling a large number of circuits, or the use of a single tube in closely confined quarters.

The semi-transparent cathode surface on the glass window in the large end of the 1P42 is sensitive to light sources predominating in blue radiation, and has negligible sensitivity to infrared radiation. The tube has an S-4 spectral response and maximum response at a wavelength of 4200 Angstroms.

The RCA-1P42 is especially designed for compact services such as the control of complex business-machine operations. It is also applicable to small equipment for sound-film reproduction.

A technical bulletin on the RCA-1P42 is available on request. RCA tube application engineers will be glad to work with you in adapting this or any other RCA tube types to your equipment designs. Address RCA, Commercial Engineering, Section D-18K, Harrison, N. J.

RATINGS AND CHARACTERISTICS

MAXIMUM RATINGS, ABSOLUTE VALUES:

Anode-Supply Voltage (DC or Peak AC) . . .	150 max. Volts
Cathode-Current Density . . .	14 max. Microamp/sq. in.
Average Cathode Current* . .	0.4 max. Microampere
Ambient Temperature	75 max. °C

CHARACTERISTICS:

Maximum Dark Current at 150 volts . . .	0.005 Microampere
Sensitivity:	
At 4200 Angstroms	0.020 Microamp/uwatt
Luminous**	25 Microamp/lumen

MINIMUM CIRCUIT VALUES:

DC Load Resistance	1 Megohm

*On basis of the use of a sensitive cathode area 0.19" in diameter.

**Given for conditions where a Mazda projection lamp operated at a filament color temperature of 2870°K is used as a light source. With daylight, the value is several times higher; with light from a high-pressure arc, many times higher.

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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

Published Monthly by

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VOLUME 34 — *November, 1946* — NUMBER 11

PROCEEDINGS OF THE I.R.E.

INSTITUTE NEWS AND RADIO NOTES

WAVES AND ELECTRONS

SECTION

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The amazing technical development and industrial expansion of the radio field could not have occurred without the intelligent and determined efforts of the engineers active in that field. Its further progress will be in considerable measure dependent on the same group. Accordingly some engineers have of late been called to high executive positions in industry. Reflecting these trends, there is here presented an editorial from a former President of The Institute of Radio Engineers who has long been constructively active in the radio field and who is as well the present president of the Stromberg-Carlson Company.—*The Editor.*

Radio Industry Needs Well-Trained Young Engineers

RAY H. MANSON

The radio industry needs young engineers of the highest caliber. The radio business is not static. Recent advances in fundamental approaches to the sciences underlying electronics, as well as the rapid expansion in the applications of electronics, offer a challenge to the very highest grade of engineer.

At the present time there are almost endless opportunities for well-trained radio engineers who have had formal education in electronics and communications in up-to-date electronic techniques. Most young engineers are probably primarily interested in working in engineering laboratories on the development and design of circuits and apparatus or in the production and inspection of radio equipment. Others—and especially those with advanced training—find their chief interest in research laboratories, where advances are made in the fundamental knowledge underlying engineering.

Practically all modern designs of electronic equipment demand the exercise of great ingenuity and the ability to co-ordinate the electrical design with the mechanical requirements, in order that the finished product not only will be efficient in operation but will be practical in design and capable of production in the factory with modern manufacturing methods. Last, but not of least importance, is the necessity that the product can be manufactured and sold in a competitive market at a reasonable profit.

Radio, being a highly competitive business, with major success coming to those who lead in new products, requires that an engineer be able quickly to recognize the fundamentals of each problem and, through clear thinking backed by experience, quickly provide a useful and practical design.

In recent years, more and more engineers have worked into supervisory and managerial positions in all branches of the radio industry, and such possibilities are available in all phases of industrial work. It should be noted, however, that top-notch engineers, doing strictly technical work, form the keystone of the radio industry. Such men should—and usually do—have equal or greater recognition and earning capacity than those in all but top supervisory and management positions.

The electronic field is still in its infancy. The rapid advance in the last few years into the field of frequencies hitherto unexplored has opened seemingly limitless opportunities for the electronic engineer of the future. To the young, well-trained engineer, it offers a challenge with ample rewards for successful accomplishment.

Edward M. Webster

Board of Directors, 1946

Edward M. Webster was born February 29, 1889, in Washington, D. C. He was graduated from the United States Coast Guard Academy in 1912 as an ensign; during World War I he served with the Navy, following which he was assigned to communications duty in the Coast Guard, and was its chief communications officer.

Retiring from active duty in 1934, Commodore Webster accepted a position with the Federal Communications Commission as assistant chief engineer, in which his work included the regulation of the use and installation of radio in the merchant marine. Recalled to active duty in the Coast Guard in 1942, he was assigned to his former duty as chief communications officer with the rank of captain, and in 1945, was promoted to rank of commodore.

As the representative of the United States, he has attended the International Radio Conferences of Washington, 1927; Madrid, 1932; Cairo, 1938; the Inter-American Radio Communications Conference, Rio de Janeiro, 1945; and the London Safety of Life at Sea Conference in 1929.

During 1946, Commodore Webster has attended several international conferences involving aviation operations, and the questions of safety communications and search and rescue over and on the high seas; all under the aegis of the Provisional International Civil Aviation Organization. In March of this year he attended the International Meeting on Radio Aids to Marine Navigation, in London, as chairman of the United States delegation. As a member of a technical investigating committee for the United States Senate several years ago, he assisted in the drafting of congressional legislation, subsequently enacted into law, which put into effect the radio provisions of the International Convention for Safety of Life at Sea.

Commodore Webster was relieved from active duty in the Coast Guard August 1, 1946, and is now director of telecommunications with the National Federation of American Shipping, Inc.

In 1930 he became an Associate member of the Institute of Radio Engineers, transferred to Member grade in 1938, to Senior Member grade in 1943, and in 1944 received a Fellow Award. He served on the Membership Committee in 1940, on the Public Relations Committee in 1945, was secretary of the Washington Section in 1940, and chairman in 1942. He is a member of the Veterans Wireless Operators Association.

Metal-Lens Antennas*

WINSTON E. KOCK†, SENIOR MEMBER, I.R.E.

Summary—A new type of antenna is described which utilizes the optical properties of radio waves. It consists of a number of conducting plates of proper shape and spacing and is, in effect, a lens, the focusing action of which is due to the high phase velocity of a wave passing between the plates. Its field of usefulness extends from the very short waves up to wavelengths of perhaps five meters or more. The paper discusses the properties of this antenna, methods of construction, and applications.

Introduction

THE EXTENSION of the useful field of radio waves to the very short wavelengths has made the optical properties of such waves increasingly apparent, and effective use of this optical nature has already been made in employing concave parabolic mirrors as radio antennas. Another optical device which can function as a radio antenna is the lens; it performs in a manner similar to a parabolic reflector in that it transforms the spherical wave front produced by rays emerging radially from a smaller feed antenna into a flat or uniphase wave front at the aperture of the lens.

The usual glass or dielectric lenses of optics depend, for their focusing action, upon the fact that free-space electromagnetic waves experience a reduction in velocity upon entering a dielectric medium. The lens to be described in this paper depends upon imparting to the waves an increased phase velocity rather than the usual slower velocity of a dielectric lens. Its operation is based on the fact that electromagnetic waves confined in wave guides assume a wavelength and phase velocity which are greater than their free-space wavelength and velocity.[1] This same property is acquired by waves confined between conducting plates which are parallel to the electric vector and spaced apart a distance greater than one half wavelength. A row of such parallel plates accordingly constitutes a refractive medium with index of refraction less than unity. Such a medium, when cut to the proper profile, can be used to produce a focusing or lens effect in a manner similar to that of a dielectric lens.

Fig. 1 shows how both types of media can be used to obtain the focusing action of a lens; in the case of the metal-plate refracting medium, a concave profile is required.

Fundamental Principles

The phase velocity of the dominant mode of a transverse electric wave confined between conducting plates which are parallel to the electric vector and infinite in extent is given by

$$v = v_0/\sqrt{1-(\lambda/2a)^2} \tag{1}$$

where a is the separation of the plates or side walls, v_0 is the free-space velocity, and λ the free-space wavelength. The equivalent index of refraction, which is the ratio of free-space velocity to velocity in the medium, is then

$$n = \frac{v_0}{v} = \sqrt{1-\left(\frac{\lambda}{2a}\right)^2}. \tag{2}$$

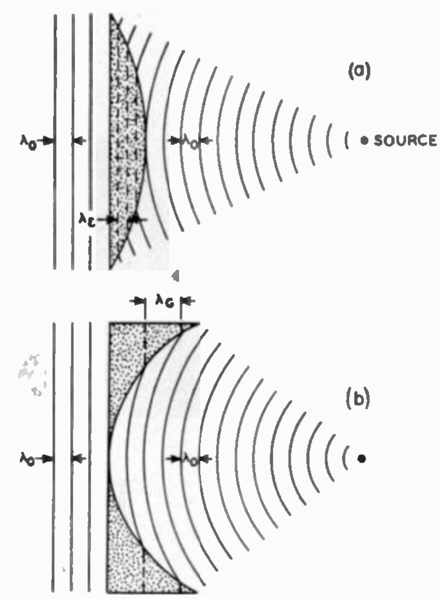

Fig. 1—Focusing action of (a) dielectric and (b) metal-plate lenses.
λ_0 = Free-space wavelength.
λ_ϵ = Wavelength in the dielectric.
λ_G = Wavelength in the guide.

It is seen that, for any finite plate spacing a greater than one-half wavelength, n is finite and less than one.

The required profile of a metal-plate lens can be

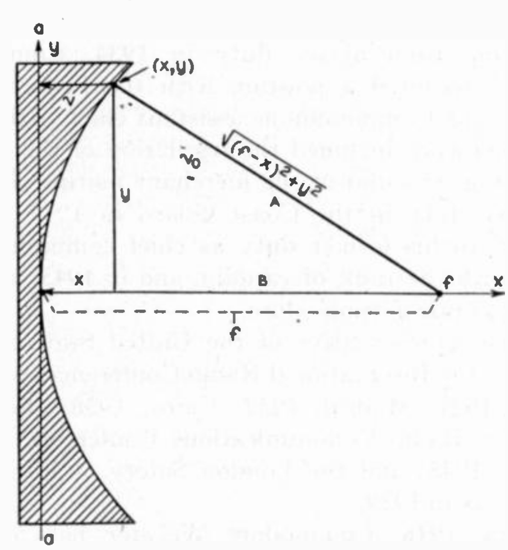

Fig. 2—Calculation of lens profile.

* Decimal classification R326.8. Original manuscript received by the Institute, March 29, 1946; revised manuscript received, June 25, 1946.
† Bell Telephone Laboratories, Inc., Holmdel, New Jersey.
[1] The use of the increased phase velocity in a wave guide to obtain a lens or prism action was considered rather early by A. P. King, G. C. Southworth, and W. P. Mason of these Laboratories.

determined by ray analysis. Thus, in Fig. 2, it is required that the phase of ray A should equal that of ray B at the aperture a–a. That is,

$$\sqrt{(f-x)^2+y^2}/v_0 + x/v = f/v_0 \tag{3}$$

or

$$(1-n^2)x^2 - 2(1-n)fx + y^2 = 0 \tag{4}$$

where $n = v_0/v$. This is the equation of an ellipse, having a radius of curvature, at $y=0$, of

$$\rho = f(1-n). \tag{5}$$

If a number of identical metal plates having the profile defined by equation (4) and shown shaded in Fig. 2, are placed side by side with proper center-to-center spacing, one obtains a lens which focuses in only one plane, i.e., a "line-focus" lens. If, on the other hand, the

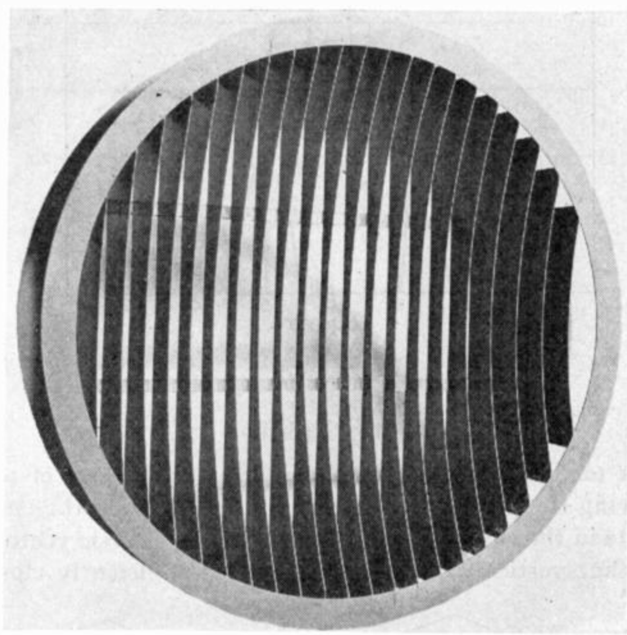

Fig. 3—A plano-concave metal lens having an aperture of 14 wavelengths.

plates are cut out and assembled so as to form, for the rear face, a surface of revolution generated by revolving the ellipse defined by (4) about the x axis, one obtains a circular lens which focuses in both planes (point focus). Such a lens, 14 wavelengths in diameter and having an f number (ratio of focal length to aperture) of 1.67, is shown in Fig. 3.

In order to keep the lens thickness at a minimum the process of stepping can be employed, whereby the lens profile is reduced each time a thickness is reached which is equivalent to a phase advance of one wavelength. This thickness t depends upon the wavelength and the index of refraction, as follows:

$$t = \frac{\lambda}{1-n} \tag{6}$$

so that the equations of the successive steps are altered as shown in Fig. 4. Such a stepped lens 40 wavelengths square is shown in Fig. 5.

By employing plates of the proper shape, lenses can be designed to produce almost any desired directional pattern in either the vertical or horizontal planes. This would permit the design of transmitting antennas which

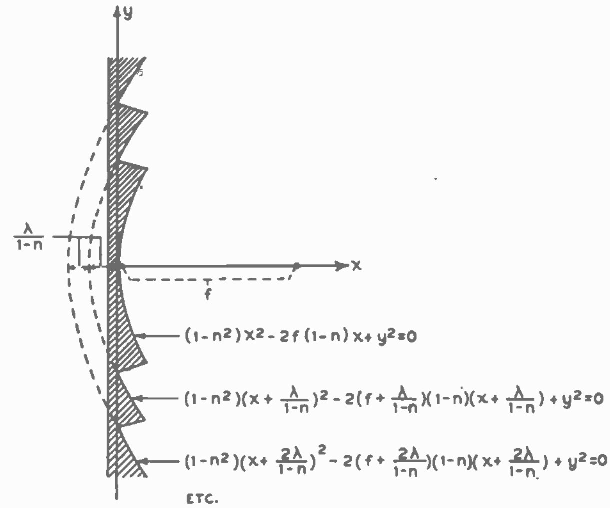

Fig. 4—Equations of successive steps of a metal plate lens.

would have good coverage over certain areas and reduced coverage over others, and receiving antennas which would receive with high gain only in certain

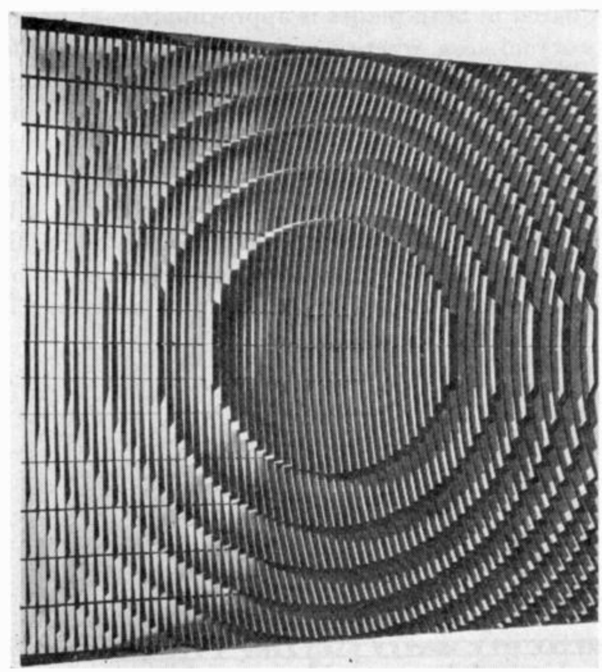

Fig. 5—An $f/0.95$ metal lens of stepped construction.

selected directions and discriminate against other directions from which unwanted signals arrive. However, in this paper, consideration will be given only to those lens antennas which finally produce a flat or uniphase surface at their aperture, inasmuch as such antennas possess, for a given aperture area, the greatest directivity and gain.

Horn-Lenses

An important type of lens antenna is a combination of a lens and electric horn. The flare angle of a horn radiator is generally designed to produce maximum gain for a given horn length; i.e., "optimum" design.[2] For large-aperture horns the required length becomes excessive, and a lens in the aperture can materially reduce this horn length. For example, the lens shown in Fig. 5 has an aperture of 40 wavelengths and is designed for use with a square pyramidal horn 38 wavelengths long; an optimum horn flared to an aperture of 40 wavelengths in the electric plane would be 800 wavelengths long. This striking difference in length is shown to scale in Fig. 6. Increased gain over an optimum horn is also

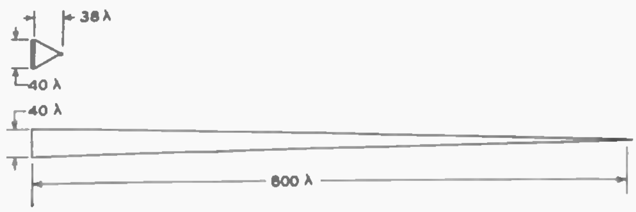

Fig. 6—Comparison of horn lengths of 40-wavelength-aperture antennas. Above: horn with lens of Fig. 5 in the aperture. Below: optimum horn (no lens).

achieved by the use of a lens, since, by proper design of the lens, the gain can be made to approach that of an infinitely long horn. The effective area of an optimum horn flared in both planes is approximately 45 per cent of its actual area, whereas a similar horn infinitely long has an effective area which is 81 per cent of its actual area.[3] This increase in effective area is equivalent to a 2½-decibel increase in power gain of the horn.

If the horn, instead of being pyramidal, i.e., flared in two dimensions, is flared in one dimension only, a lens in the aperture can also materially reduce the required horn length. Fig. 7 shows a sketch of such a horn equipped with a lens of 36 wavelengths aperture. This

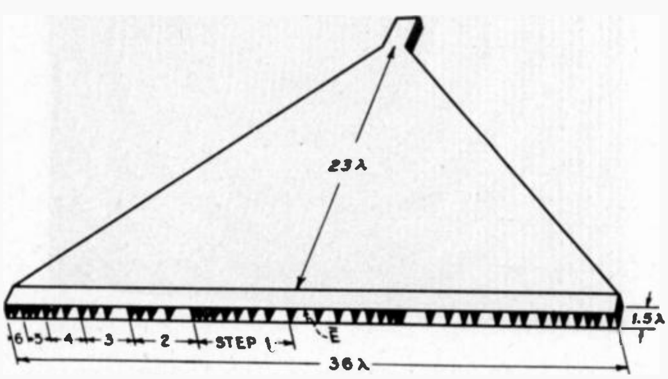

Fig. 7—Sectoral horn equipped with a wave-guidel ens.

lens is of a type somewhat different from those so far discussed. It is a lens having constant thickness and varying index of refraction and consists of a number of wave guides of constant length (1½λ) but of different widths (different phase velocities). The phase velocities of the individual wave guides are chosen so that proper phase advance is secured in the 1½λ length of guide, and the circular phase front of the wave approaching the lens from the throat of the horn is thereby transformed into a flat emerging phase front. The stepping procedure is also made use of in this lens, as shown in the sketch. Since the focal length of the lens is 23 wavelengths, it has an f number of 0.64. This antenna produces a narrow beam in the horizontal plane (the plane of the horn flare) and a broad beam in the vertical plane. The horizontal directional pattern is shown in Fig. 8.

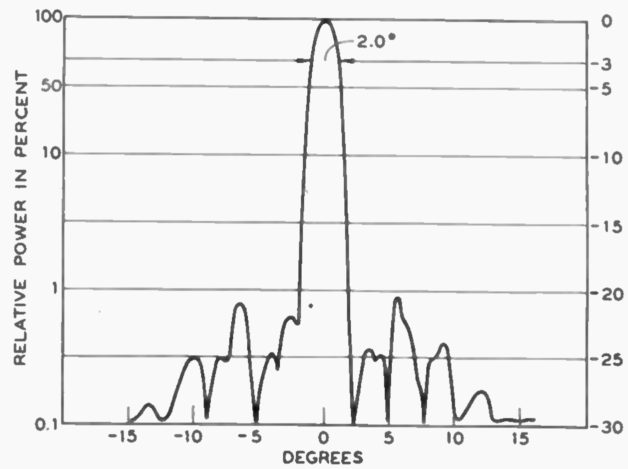

Fig. 8—Directional characteristic of a sectoral horn having an f/0.64 lens in the aperture.

Wire Lenses

A modification of the solid plate lens consists of replacing the plates with wires. In a wave guide the currents in the side walls are parallel to the electric vector, so that vertical rods or wires, spaced sufficiently close

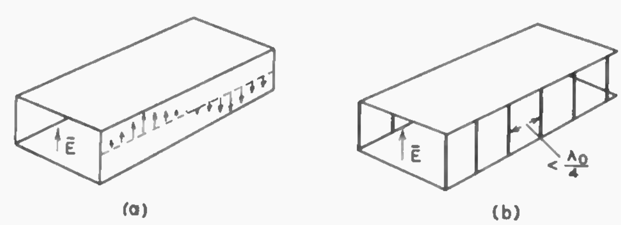

Fig. 9—(a) Current in side walls of conventional wave guide for dominant mode. (b) Nonradiating wave guide having wire side walls.

together, can be used to replace the solid side walls (Fig. 9). Since the plates of a metal-plate lens are also wave-guide side walls, they likewise can be constructed of wires. Experimentally it was found that the spacing of the wires in such a lens plate could be as much as one quarter of the free-space wavelength without serious effect on the lens performance. A wire lens, 7.3 wavelengths in diameter, is shown in Fig. 10; it exhibited 50 per cent effective area with side lobes 18 decibels down in the magnetic plane and 20 decibels down in the the electric plane. The widths of the major lobe at half-power points were 8.5 degrees and 8.7 degrees in the two

[2] W. L. Barrow, and L. J. Chu, "Theory of the electromagnetic horn," Proc. I.R.E, vol. 27, pp. 51–64; January, 1939. See also F. E. Terman, "Radio Engineers Handbook," p. 824, McGraw-Hill Book Company, New York, N. Y.

[3] S. A. Schelkunoff, "Electromagnetic Waves," p. 365, D. Van Nostrand Company, Inc., New York, N. Y., 1943.

planes. This construction would be useful at meter wavelengths where the wire spacings are large and the lens plates could be curtains of wires suspended from poles.

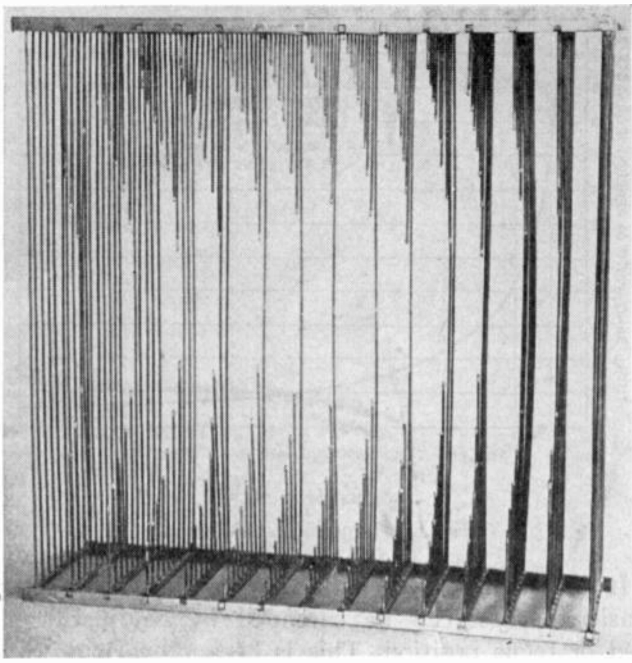

Fig. 10—Wire-curtain lens.

Feed Systems

Lens feeds can be those employed with parabolic reflectors; namely, directive dipole feeds (Fig. 11(a)) or small wave-guide horns (Fig. 11(b)). When thus used, the directivity of the feed is usually designed to produce an illumination across the aperture which is

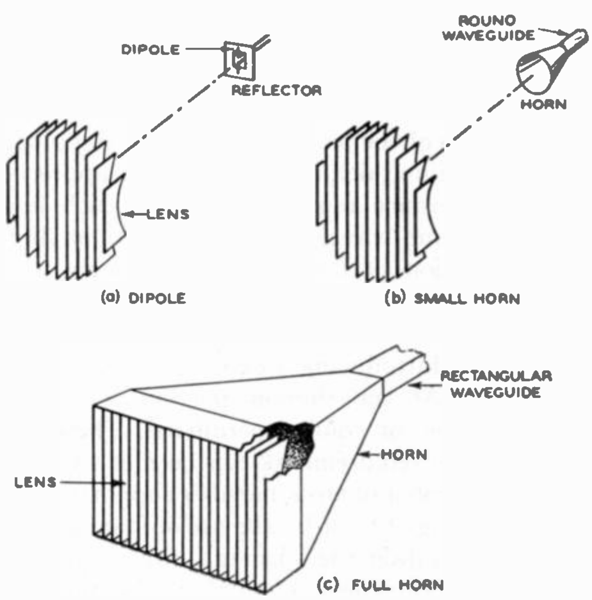

Fig. 11—Methods of energizing metal lenses.

tapered, being down approximately 10 decibels at the edges of the lens. Somewhat superior results are obtained if the feed horn is made longer than optimum so as to improve its primary directional pattern. For lenses with large *f* number, the feed horn must have high directivity and consequently a large aperture in wavelengths. As a horn may then become unduly long, it may be preferable to use instead a second lens as a feed, this second lens being fed in turn by a small wave-guide horn. Such an arrangement is shown in Fig. 12; in this photograph the round wave-guide horn can be seen behind the smaller "primary" lens.

Another method of feeding a lens, which is not applicable in the case of parabolic reflectors, comprises the use of a horn with sides extending to the edges of the lens (Fig. 11(c)). The horn is made equal in length to the focal length of the lens and prevents energy from spilling over the edges of the lens. This type of lens feed may be said to be well "shielded"; it is useful in applica-

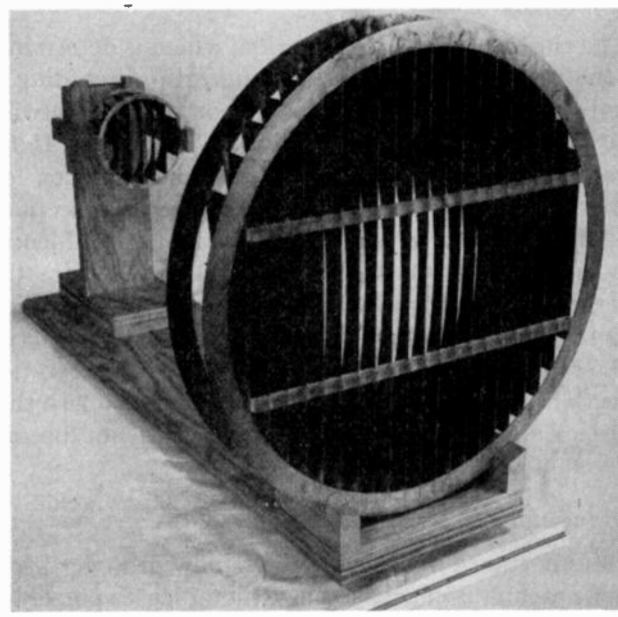

Fig. 12—Double-lens system.

tions where interference between two adjacent simultaneously operating antennas is to be kept at a minimum. Furthermore, it has been found that this type of feed is easier to match to the feed line than a small horn feed. The aperture of a small horn usually presents a sizeable mismatch to free space and this must be tuned out, with the result that a good match over a broad band is difficult to obtain. A horn extending to the edges of the lens has such a large aperture that it matches free space quite well, and the small mismatch remaining at the throat can be tuned out over a large band. The presence of the lens will affect the match in either cases, but this effect can be minimized by tilting the lens slightly. This procedure will be discussed in the following section.

Design Considerations

1. Constructional Details

Methods of construction of metal lenses will depend upon the wavelength at which they are to be used and upon the type of lens. At meter wavelengths the wire-curtain construction is most applicable, whereas at shorter wavelengths the solid-metal-plate structure is perhaps more suitable.

For the solid metal-plate variety, some of the newer low-loss dielectric foam materials can be used as spacers between very thin metal plates. Bonding the metal to the foam strips forms a very light structure which is sufficiently rigid for some applications.

The usual construction methods employ sheet metal for the lens plates, which are individually cut out. Since the electric vector is parallel to the plates, numerous metal cross supports can be introduced without interfering with the lens performance. By using an interlocking-slot (egg-crate) construction, a rigid cellular structure is obtained. (See, for example, Fig. 20.)

2. *Index of Refraction*

The choice of index of refraction, which is determined by the wavelength-to-plate spacing ratio, according to equation (2), will be based upon a compromise between two factors, reflection loss and lens thickness. If the refractive index is too small, undesirable reflection loss occurs at the lens surface, so that matching sections, similar to the quarter wave films used on optical lenses, may be required. On the other hand, if the refractive index is too large (too close to unity), the lens thickness becomes undesirably large. An index of refraction of 0.6 represents a fair compromise, since the theoretical reflection loss at each surface is then held to less than 0.1 decibel, and the lens thicknesses do not become unreasonable.

3. *Bandwidth of Metal Lenses*

Of importance in design is the bandwidth over which a lens antenna is effective. Since metal lenses possess an index of refraction which varies with the wavelength (equation 2), they are frequency sensitive. This means that at frequencies other than the design frequency the lens either undercorrects or overcorrects the spherical wave emanating from the feed, and instead of the resulting wave front being flat (as indicated in Fig. 1 (b)), it becomes curved, and the antenna performance is thereby impaired. To evaluate the frequency band over which such a lens will operate efficiently, some criterion must be set up for the amount of this wave front or phase curvature which can be tolerated. Because of the tapered illumination usually employed in a lens, the edges of the lens, where the phase error is greatest, are not strongly energized, so that this particular type of phase variation does not have as pronounced an effect on the antenna performance as a random phase variation. Experimentally it has been found that whereas the random phase variation should be kept less than $\pm\lambda/16$, a curved phase discrepancy of $\pi/2$ (i.e., $\pm\lambda/8$) between the center and edges of the lens can be satisfactorily tolerated. Applying this $\pi/2$ phase limitation, the bandwidths of both stepped and unstepped lenses can be calculated, as has been done in Appendix I, and the results plotted in Fig. 13. It is seen that the bandwidth can be improved by the process of stepping, since this reduces the path length of the rays in the frequency-sensitive medium. In Fig. 13 the index of refraction has been taken as 0.5; somewhat broader bands are obtained if the value of 0.6 is chosen.

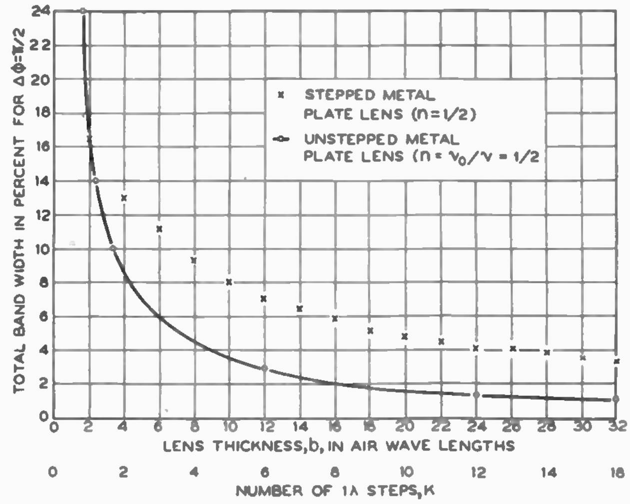

Fig. 13—Bandwidths of lenses.

It may be observed that the bandwidth of frequency-sensitive lenses can be extended by readjusting the feed or focus position. This is because various wavelengths tend to focus at different points along the lens axis.

4. *Tolerance Considerations*

Another design requirement is a knowledge of construction tolerances which are permissible in a metal-plate lens. Three tolerances are of importance: plate-spacing tolerance, profile or thickness tolerance, and twist or warping tolerance. Plate-spacing tolerance is analyzed in Appendix II, and it is seen that since, for a given phase accuracy, the plate spacing must be more accurately maintained at the thick portions than at the thin portions of the lens, the process of stepping, by which the maximum thickness is minimized, appreciably relieves the tolerance requirements. For such lenses, stepped at the one wavelength points and having an index of refraction of 0.6, the plate spacing at the thickest portions of the lens (i.e., the tips of the steps) may vary ± 2.2 per cent from the correct design spacing without introducing a phase error greater than $\pm\pi/8(\pm\lambda/16)$. At the thinner portions of the lens more tolerance is, of course, permitted. These plate-spacing tolerance requirements can be met by the use of a sufficient number of cross-member supports (shown, for example, in Fig. 20), or by the use of foam separator sheets which maintain the spacing quite accurately.

The profile or thickness tolerance is the amount by which the contour of the plates may vary from their theoretically correct contour, as defined by the equations of Fig. 4. As shown in Appendix II, if the actual thickness of a point on the lens differs from its true design thickness b by an amount Δb, then the phase discrepancy in wavelengths, $\Delta\lambda$, is given by

$$\Delta\lambda = \Delta b(1 - n). \tag{7}$$

From this equation it is seen that the permissible thickness variation in a lens having an index of refraction of 0.6 is five times the tolerance of a reflector for the same phase requirements.

Consideration of the third tolerance requirement, the warping tolerance, brings out one of the most important advantages of a lens over a reflector. It will be seen below that a lens can suffer appreciable rotation (as in Fig. 14) without serious effect on the direction or quality of the beam it produces. Since any portion of the lens can likewise suffer such a displacement from its correct position without harming the lens performance, it is evident that considerable warping and twisting of the final lens structure can be tolerated.

5. Matching Problems

In antenna design it is desirable that the whole antenna unit present a satisfactory match to the feed line over its useful band. Both reflector antennas and lens antennas comprise two elements, the feed and the main reflector or lens; and although it may not be too difficult to design the feed system alone to properly match the feed line, the reflector or lens may influence the feed system, in which case the large distances in wavelengths which are usually present between feed and antenna will prevent a satisfactory match from being obtained over a broad band. In a lens antenna practically all of the energy passes on through the lens and very little is reflected back towards the feed, as in the case of a reflector. This discontinuity at the lens surfaces will cause a small amount to be reflected, and if the front surface of the lens is flat, the lens should be tilted in order to prevent this reflected energy from being refocused back into the feed. A tilt of one or two wavelengths between the extremities of the lens is sufficient to steer the reflected beam away from the feed, as shown in Fig. 14. Other ways of reducing such

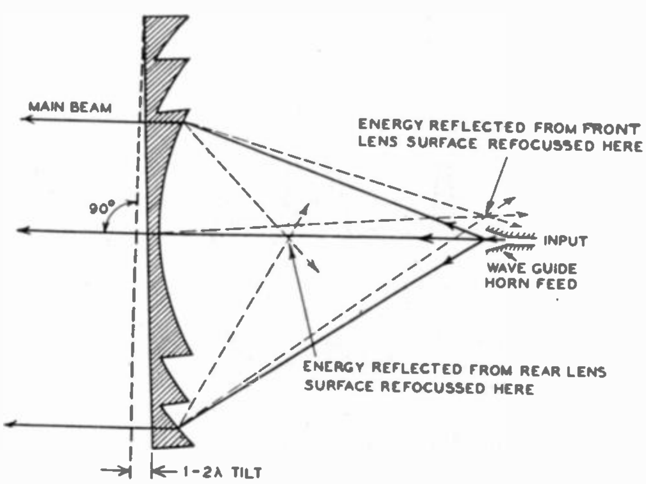

Fig. 14—Use of lens tilt to prevent reflected energy from entering and producing undesirable standing waves in feed line.

reflections comprise the use of quarter-wave matching sections on the two lens surfaces, or the use of a dielectric constant which presents a small mismatch (e.g., $n=0.6$ or larger).

Practical Considerations—Lens versus Reflector

Since accurately made parabolic reflectors and lenses of the same size have comparable gain and patterns and therefore can often be used to accomplish the same results, it is worthwhile to consider the practical aspects which may dictate the choice between the two.

1. Tolerances

One of the most significant advantages of a lens over a parabolic reflector is its ability to withstand warping or twisting without serious damage to the beam in the way of beam position, gain, and minor lobes. This property arises from the fact that the beam lies along a line projected from the feed through the center of the

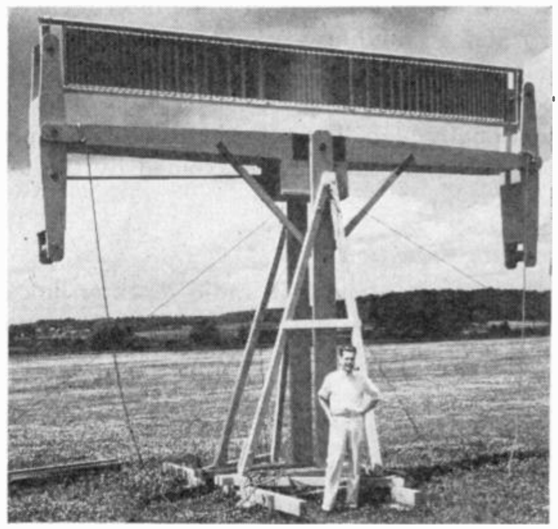

Fig. 15—Metal lens having an aperture 48 by 480 wavelengths.

lens, so that moderate angular deflections of the lens about axes passing through the center of the lens (strictly through the rear nodal point of the lens) have insignificant effects upon the beam position and directional pattern. For example, it was found experimentally that the lens of Fig. 12 could be rotated ± 33 degrees, with the feed remaining fixed, without serious effect upon the pattern or beam position and with only one decibel reduction in gain. For large-aperture short-focal-length lenses the permissible tilt or rotation is smaller but still ample to take care of any reasonable twist or warp that inadvertently may be imparted to the lens. Accordingly, as long as the lens thickness and plate spacing are correct, the mean surface of the lens can be considerably warped without seriously impairing the lens performance. A reflector, on the other hand, must be held accurately to a parabolic contour if a satisfactory gain and directional pattern is to be obtained, and the usual requirement that the phase front of the emerging wave be maintained flat to within $\pm\lambda/16$ imposes the condition that the reflector be accurate to $\pm\lambda/32$, a condition difficult to achieve for large-aperture short-wavelength antennas. For example, the metal-lens antenna shown in Fig. 15 has an aperture of 48 by 480 wavelengths,[4] and the measured gain and

[4] The construction of this lens was engineered by W. M. Sharpless of these Laboratories.

directional properties of this antenna indicated that the emerging wave front was flat to a high degree of accuracy. A reflector that large, held to the $\pm\lambda/32$ tolerance, would have presented a difficult design problem. It may be of interest to point out that the beam of this antenna is probably the sharpest radio beam ever produced, its half-power width being but 6 minutes (one tenth of a degree).

2. *Feed Position*

The relative position of the feed and the antenna leads to certain advantages in the case of a lens. In a reflector, any symmetrical arrangement of feed and reflector causes the feed to be in the way of the reflected beam, which results in some interference to the pattern and a standing wave in the feed line. This is particularly true in the case of a symmetrical sectoral parabola, where the energy reflected back into the feed is exceptionally high. The considerations in the previous section show that this can be avoided by the use of a lens.

3. *Crosstalk Protection*

In the use of antennas in radio repeater-link operations, the receiving and transmitting antennas are placed back to back and it is desirable that the inter-

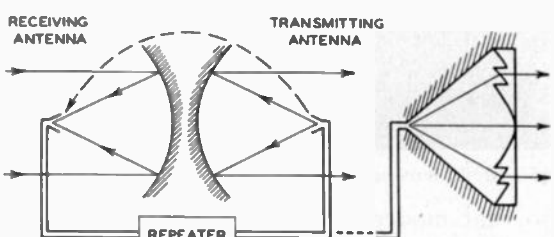

Fig. 16—Superior shielding between transmitter and receiver by the use of horn antennas with lenses.

action or crosstalk between them be kept at a minimum. In using paraboloids for such applications it is very difficult to prevent energy from the feed from diffracting around (spilling over) the edges of the dish to produce back lobes which cause crosstalk. Horn antennas are free from this spill-over difficulty and a lens in the aperture permits the use of very short horns. Such antennas are markedly superior to paraboloids in the matter of crosstalk protection (see Fig. 16). Furthermore, the rigid lens structure in the aperture furnishes a convenient mechanical support for a dielectric cover for protection against ice formation. As indicated above, the large horn will also present a superior match to the feed line compared with the customary paraboloid feed.

4. *Bandwidth*

On the other hand, the lens has a definite bandwidth limitation which the reflector does not possess, and, except for the problem of match to the feed line, the reflector is truly a broad-band antenna (a searchlight mirror can be used equally well for light waves or radio waves). Also, the presence of the steps in a lens causes a slight distortion of the wave front due to diffraction of the waves at the step boundaries. Although this effect is apparently small, it may account for the failure to obtain the expected 81 per cent effective area of a horn-lens combination (see next section).

Experimental Results

In this section, the results of tests on several experimental models will be given. Figs. 17 and 18 show, re-

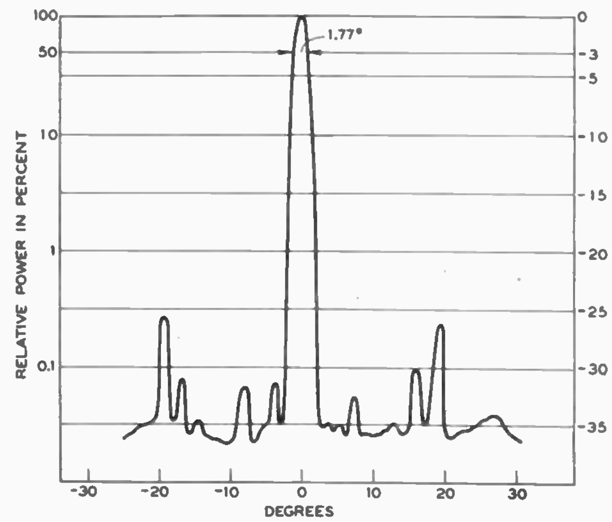

Fig. 17—Electric-plane pattern of 40-wavelength-square metal-plate lens.

spectively, the electric and magnetic plane patterns of the 40-wavelength-square-aperture lens of Fig. 5, when energized by a conical feed horn having an aperture 2 wavelengths in diameter. From the curve of Fig. 13 this

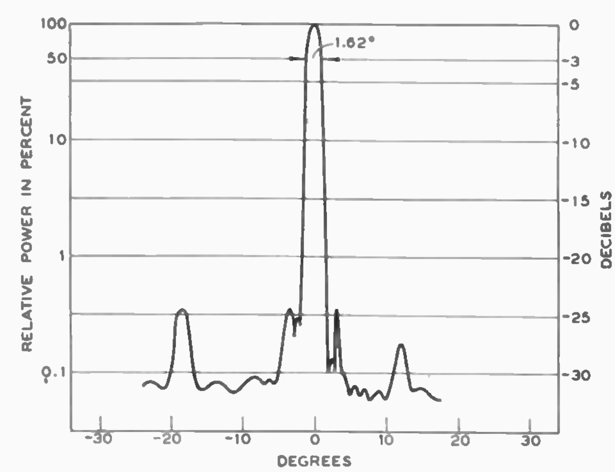

Fig. 18—Magnetic-plane pattern of 40-wavelength-square metal-plate lens.

lens should have a bandwidth of 8 per cent, and Fig. 19 shows its behavior over a 12 per cent band of frequencies; although the gain and beam width are seen to be affected, the direction properties remain quite good.[5] When this lens is used in conjunction with a horn 38 wavelengths long, extending to the edges of the lens, the

[5] This and similar results on other lenses form the basis for the statement made earlier that a phase-front curvature of $\lambda/4$ does not have too serious an effect on antenna performance.

patterns are similar, except that in the electric plane the illumination is more uniform and the directional characteristic approaches the expected sin x/x pattern produced by a uniform-amplitude, uniform-phase antenna. With a $\pm\frac{5}{8}\lambda$ tilt imparted respectively to the top and bottom of the lens relative to the center, the standing-wave ratio in the horn throat averaged 0.5 decibel (voltage-standing-wave ratio = 1.06) over a 10 per cent band of wavelengths, reaching a maximum of 0.7 decibel at several points.

Experiments were made to determine the extent to which the gain of a horn-lens antenna could be made to approach the gain of an infinitely long horn (81 per cent effective area). In one case a lens was placed in front of an optimum horn (the lens being just strong enough to correct the $\lambda/4$ phase curvature present in the horn), and the horn then exhibited an effective area of 75 per cent. In another case a short horn, 14 wavelengths long, with a $9\frac{1}{4}$-wavelength square lens in the aperture, exhibited an effective area of 66 per cent.

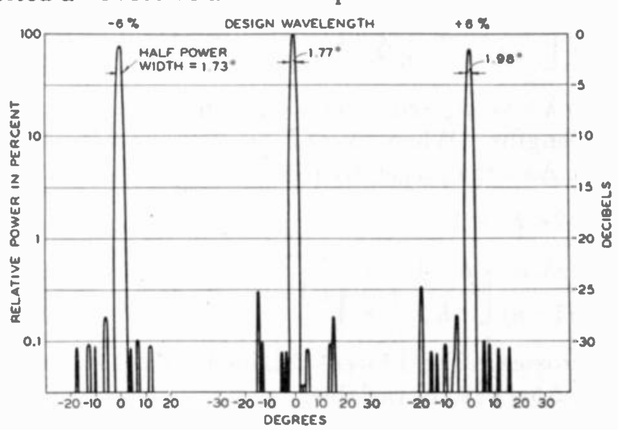

Fig. 19—Lens performance over a 12-degree wavelength band.

In general, however, it is more reasonable to expect but 50 to 60 per cent effective area from antennas where the apertures in wavelengths are large, and this has been the experience with most of the lenses illustrated in this paper. As mentioned earlier, diffraction at the steps may be responsible for the failure to realize the high expected gains.

Metal-Plate Optics

In addition to lenses, many of the other optical instruments used at light wavelengths can be duplicated at radio frequencies by the use of the metal-plate refractive medium.

Lens Applications

In the meter-wavelength region, the wire-curtain lens antenna may find application wherever pine-tree antennas have usefulness. The lens of Fig. 10 would scale to an 84- by 84-foot antenna at 3 meters, the wires being spaced $2\frac{1}{2}$ feet apart in each curtain and the curtains spaced $6\frac{1}{4}$ feet apart. The feed for this antenna could be a small array of dipoles with reflector curtain. An equivalent pine-tree antenna would require over 200 half-wave dipoles carefully phased plus a like number comprising the reflecting curtain.

Lenses in combination with horns exhibit such a small amount of interaction or crosstalk that their use as repeater antennas may permit straight-through operation of the entire repeater chain at the same wavelength, with radio-frequency amplifiers at each repeater station. In Fig. 20 is shown a photograph of a horn-lens combination designed for a repeater antenna at 4000 megacycles. It exhibited a power gain of 12,000 over an isotropic radiator. At approximately 1.8 degrees off the axis of the beam, the power gain of this antenna drops to one one-hundredth of its maximum value; this indicates that the energy is highly concentrated in a narrow beam, a property which is very desirable for repeater-link application. In actual use, the lens will be covered with a flat sheet of plastic to prevent ice from forming in the individual lens cells. With this cover in place, the standing wave in the feed line did not exceed 0.6 decibel (voltage-standing-wave ratio 1.07) over a 400-megacycle band. Fig. 21 shows a section of this lens, and Fig. 22 is a photograph taken at the horn throat (looking into the horn) showing the circular step construction.

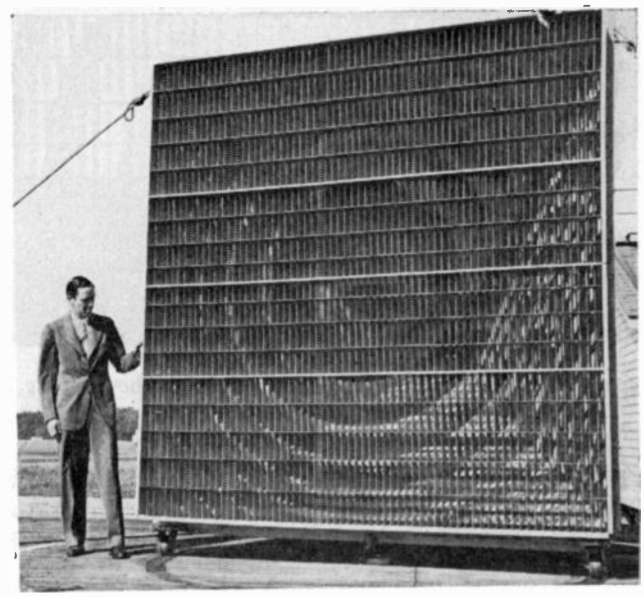
Fig. 20—4000-megacycle repeater antenna.

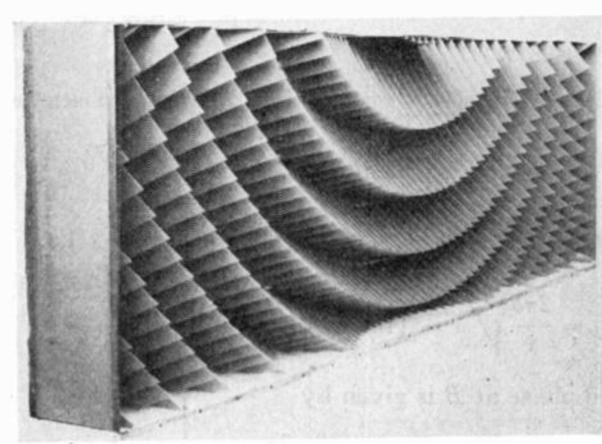
Fig. 21—Section of the lens of the antenna shown in Fig. 20.

In general, the low tolerance requirements on metal lenses make them attractive in many applications where reflectors might otherwise be used.

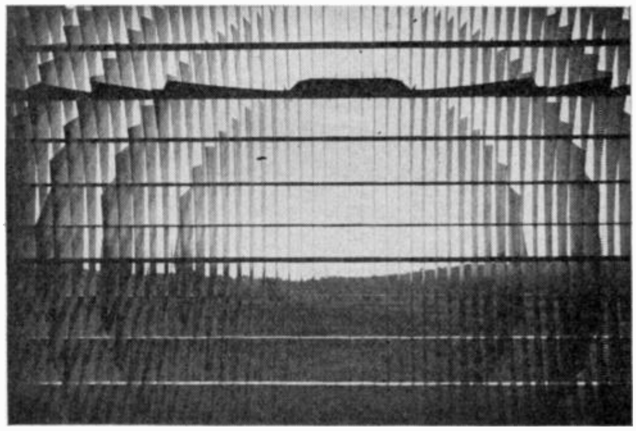

Fig. 22—View from the horn throat of the antenna shown in Fig. 20.

Acknowledgment

The author wishes to express his appreciation to his colleagues at the Holmdel Radio Research Laboratory for assistance and co-operation in the course of this work.

Appendix I

Band-Width Considerations

1. *Unstepped Metal Lenses*

In Fig. 23(a) the phase at A is given by

$$\phi_A = \frac{2\pi b}{\lambda_g} = \frac{2\pi b}{\lambda}\sqrt{1-\left(\frac{\lambda}{2a}\right)^2} \quad \text{where } b \text{ is the lens thickness.} \tag{8}$$

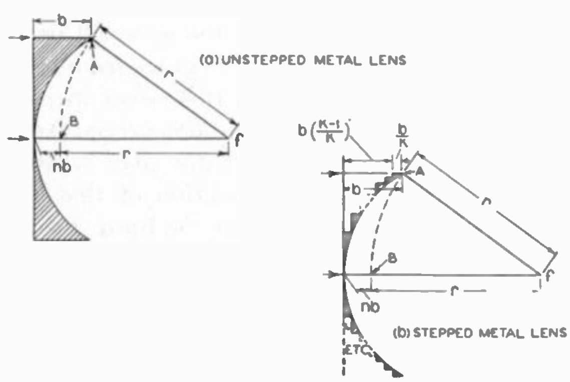

Fig. 23—Bandwidth considerations. (a) Unstepped metal lens. (b) Stepped metal lens.

At the design wavelength λ_0,

$$n = \sqrt{1-\left(\frac{\lambda_0}{2a}\right)^2} \quad \text{or} \quad \left(\frac{1}{2a}\right)^2 = \frac{(1-n^2)}{\lambda_0^2}, \text{ i.e.,}$$

$$\phi_A = \frac{2\pi b}{\lambda}\sqrt{1-(1-n^2)\left(\frac{\lambda}{\lambda_0}\right)^2}. \tag{9}$$

The phase at B is given by

$$\phi_B = \frac{2\pi}{\lambda} nb, \tag{10}$$

so that

$$\Delta\phi = \phi_A - \phi_B = \frac{2\pi b}{\lambda}\left[\sqrt{1-(1-n^2)\left(\frac{\lambda}{\lambda_0}\right)^2} - n\right]. \tag{11}$$

The solid curve in Fig. 13 was obtained from (11) by letting $n=0.5$, $\phi_A-\phi_B=+\pi/2$, $\phi_A-\phi_B=-\pi/2$ and b variable.

2. *Stepped Metal Lenses*

In Fig. 23(b) the thickness b of the original lens is $K\lambda_0/1-n$ where K is the number of one wavelength steps. The phase at B is $\phi_B=2\pi nb/\lambda$ and the phase at A is

$$\phi_A = \frac{2\pi b}{\lambda}\left(\frac{K-1}{K}\right) + \frac{2\pi b}{\lambda K}\sqrt{1-(1-n^2)\left(\frac{\lambda}{\lambda_0}\right)^2} \tag{12}$$

so that

$$\phi_A - \phi_B = \frac{2\pi b}{\lambda}\left[\frac{K-1}{K} + \frac{1}{K}\sqrt{1-(1-n^2)\left(\frac{\lambda}{\lambda_0}\right)^2} - n\right]. \tag{13}$$

When $\lambda=\lambda_0$, $\phi_A-\phi_B=2\pi(K-1)$, an integral number of wavelengths. When $\lambda\neq\lambda_0$, $\phi_A-\phi_B=2\pi(K-1)\pm\Delta\phi$, where $\Delta\phi=$ the phase discrepancy. That is,

$$\Delta\phi = 2\pi(K-1) - \frac{2\pi\lambda_0 K}{\lambda(1-n)}\left[\frac{K-1}{K} + \frac{1}{K}\sqrt{1-(1-n^2)\left(\frac{\lambda}{\lambda_0}\right)^2} - n\right]. \tag{14}$$

The crosses in Fig. 13 were obtained from (14) by letting $n=\frac{1}{2}$, $\Delta\phi=\pi/2$, K variable.

Appendix II

Lens Tolerances

In Fig. 23(a)

$$\phi_A - \phi_B = \frac{2\pi b}{\lambda}\left[\sqrt{1-\left(\frac{\lambda}{2a}\right)^2} - n\right]. \tag{15}$$

The correct plate spacing a_0 is such as to make

$$\sqrt{1-\left(\frac{\lambda}{2a_0}\right)^2} = n \quad \text{or} \quad \left(\frac{\lambda}{2}\right)^2 = (1-n^2)a_0^2. \tag{16}$$

Substituting in (15),

$$\phi_A - \phi_B = \frac{2\pi b}{\lambda}\left[\sqrt{1-(1-n^2)\left(\frac{a_0}{a}\right)^2} - n\right]. \tag{17}$$

This equation yields the ± 2.2 per cent figure mentioned in the text for a $\pm\lambda/16$ phase accuracy ($\phi_A-\phi_B=\pm\pi/8$, $b=\lambda/1-n$, $n=0.6$).

The thickness tolerance of a lens is directly proportional to the phase accuracy requirements. If a lens of thickness b produces a certain phase advance ϕ, then a thickness variation Δb will produce a phase variation $\Delta\phi$.

Measurement of the Angle of Arrival of Microwaves*

WILLIAM M. SHARPLESS†, SENIOR MEMBER, I.R.E.

Summary—This paper describes a method of measuring the direction from which microwaves arrive at a given receiving site. Data which have been collected on two short optical paths using a wavelength of 3¼ centimeters are presented to illustrate the use of the method. Angles of arrival as large as ½ degree above the true angle of elevation have been observed in the vertical plane, while no variations greater than ±1/10 degree have been found in the horizontal plane. These results indicate that radar directions for low angles of elevation may be in error by several tenths of a degree during times when anomalous propagation conditions are present. Possible solutions to the problems introduced by variations in the angle of arrival are suggested.

Introduction

A KNOWLEDGE of the variations likely to be encountered in the angle of arrival of radio waves has for some time been of considerable importance to radio engineers. Angle-of-arrival measurements made at short waves on signals received over the North Atlantic path from Rugby, England, to Holmdel, New Jersey[1,2], yielded information which made possible the building of special types of receiving antennas for transoceanic reception.[3]

This paper deals with angle-of-arrival observations made in the microwave region over two short, line-of-sight paths in northern New Jersey, with the terminals located less than 30 miles apart. The transmission wavelengths were in the 3-centimeter band; the results are therefore of importance to radar engineers as well as to those interested in microwave relay systems.

Variations of the angle of arrival of radio waves on a particular transmission path will, of course, have a direct bearing on the design of the antenna systems to be used on that path. A knowledge of the angles of arrival is required for the proper design of antennas in microwave repeater systems, since such antennas must accommodate the maximum variations in angle of arrival expected in both planes. Fixed point-to-point antennas must not be designed with beam-widths so sharp that the waves may, at times, arrive outside the main lobe of the antenna. Likewise, steerable antenna designs will be influenced by a knowledge of variations likely to be encountered in the angle of arrival. Target directions indicated by radar will obviously be in error if transmission conditions are such that the transmitted and received waves do not travel along straight lines while being propagated through the earth's atmosphere.

In general, microwaves propagate from point to point near the earth's surface along curved paths, the curvature being due to refraction introduced by the atmosphere. This refraction is caused by gradients of the dielectric constant of the atmosphere, which, in turn, are due principally to the distribution of temperature and moisture.

If a well-mixed atmosphere exists between the transmitter and receiver, its dielectric constant decreases slightly with height above ground (a relative gradient of about -2.4×10^{-6} per hundred feet) and we have a condition in which a so-called "Standard Atmosphere" is present. In this situation, the path traveled by the waves will have a radius of curvature equal to about four times the radius of the earth, and the waves will arrive at the receiver with an elevation angle slightly above the true elevation angle of the transmitter.[4]

Under conditions of anomalous propagation, the path of the wave may deviate from the "standard conditions" path, described above, in the following ways: (a) if the dielectric constant of the atmosphere decreases with height more rapidly than the standard rate, the wave will be refracted downward more rapidly and will arrive at the receiver at an angle of elevation higher than the "standard" angle; (b) if the dielectric constant falls off less rapidly than the standard rate, the wave path will be refracted downward less rapidly, becoming straight when the dielectric constant is uniform with height, and will be refracted upward when the dielectric constant increases with height; under the latter conditions the wave arrives at the receiver at an angle of elevation lower than the "standard" angle; (c) if more complicated variations of the dielectric constant are present in the atmosphere, a so-called "trapping" of the waves may result. Trapping could also result under (a) above if sufficiently strong gradients were present.

A rather involved meteorological situation would be required to account for some of the results obtained during times of anomalous propagation. In view of this and the fact that no meteorological air-sounding data accompany the angle-of-arrival measurements herein presented, it is believed that further discussion of propagation conditions is not within the scope of this paper.

Method of Angle-of-Arrival Measurements

The angle of arrival of the incoming waves was measured by sweeping the beam of a large receiving antenna through a small arc. The beam was swept or scanned in a sinusoidal fashion by rocking the complete antenna by means of a simple motor-driven eccentric connecting-

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† Bell Telephone Laboratories, Inc., Holmdel, N. J.

[1] H. T. Friis, C. B. Feldman, and W. M. Sharpless, "The determination of the direction of arrival of short radio waves," Proc. I.R.E., vol. 22, pp. 47–78; January, 1934.

[2] E. Bruce and A. C. Beck, "Experiments with directivity steering for fading reduction," Proc. I.R.E., vol. 23, pp. 357–371; April, 1935.

[3] H. T. Friis and C. B. Feldman, "A multiple unit steerable antenna for short-wave reception," Proc. I.R.E., vol. 25, pp. 841–917; July, 1937.

[4] This condition may be represented pictorially by drawing the earth's radius as if it were 4/3 that of true earth, and representing the transmission paths as straight lines between the terminals of the radio circuit.

rod mechanism. Observations of the signal-level output of the associated receiver as the beam of the antenna crossed through the line of the incoming waves gave an indication of the angle of arrival of the waves. For the case of a single incoming wave, the recorded output was simply a replica of the directional pattern of the scanning antenna. Both the antenna-rocking mechanism and the output-recorder chart were driven by synchronous motors.

Equipment

All the angle-measuring equipment used in these experiments was located on the top of Beer's Hill, New Jersey, near the Holmdel Laboratory. The transmitters were located at two different points, which allowed for observations on a 24-mile path to New York which was partly over water, as well as on a 13-mile path to Deal, New Jersey, which was entirely over land (see Fig. 1).

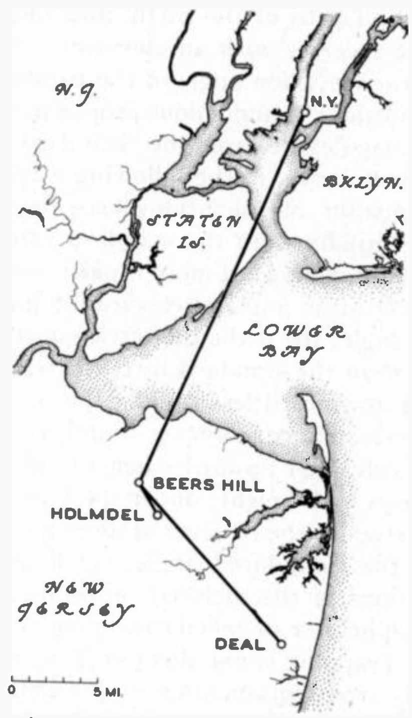

Fig. 1—Map showing location of microwave transmission paths from New York, Deal, and Holmdel to Beer's Hill, New Jersey.

The transmitting equipments, which were housed in plywood boxes for weather-proofing, consisted of 3-centimeter reflex-oscillator tubes feeding small antennas. The outputs of the oscillator tubes were monitored by directional-coupler branches feeding point-contact rectifiers from which direct-current outputs were obtained. The radiated power was about 50 milliwatts. A wave, polarized at 45 degrees, was transmitted in order that antennas that are designed for either vertically or horizontally polarized waves could be used at the receiver. The beam of the New York antenna, a 28-inch dish, was about 4 degrees wide (3 decibels down). The Deal antenna was of the lens type and was smaller, and therefore it had a slightly wider beam.

The receivers at Beer's Hill were of the double-detection type employing a 30-megacycle intermediate-frequency, point-contact first detectors, and automatic-frequency controls for the beating oscillators. The outputs of the receivers were fed through direct-current amplifiers to Esterline-Angus recorders. Two complete receiving sets were employed, the calibration of each being maintained by use of a local standard-signal generator.

The two antennas used for the measurements of the horizontal and vertical angles of arrival of the incoming waves were of the "pill-box" type, which employs a parabolic reflector between parallel plates. The reflectors had 5-foot focal lengths and 20-foot apertures. The parallel plates were spaced ½ inch apart and were flared up to a 6-inch spacing at the faces of the antennas. The antennas were constructed of plywood covered with thin copper sheets. The beams were 0.36 degree wide in the plane of the 20-foot dimension and 15 degrees wide in the other plane. These antennas were designed by W. D. Lewis of these Laboratories, who made the preliminary angle-of-arrival measurements over the New York path in June, 1944.

The two scanning antennas were mounted at right angles to each other, and the entire receiving assembly, including two other antennas and the receiving shack, was mounted on a rotatable platform which could be pointed in any horizontal direction desired (see Fig. 2). The vertical scanning antenna is shown extending skyward on the right hand side of the platform, with a 28-inch dish antenna alongside. The horizontal scanning antenna is shown on the left, extended over the edge of the platform. The 9×11 foot receiving shack toward the rear has a 30-centimeter-band antenna mounted on the roof. The wave-guide feed lines from the 3-centimeter-band antennas enter the shack through the lower part of the window. The track on which the antenna platform rotates is 25 feet in diameter.

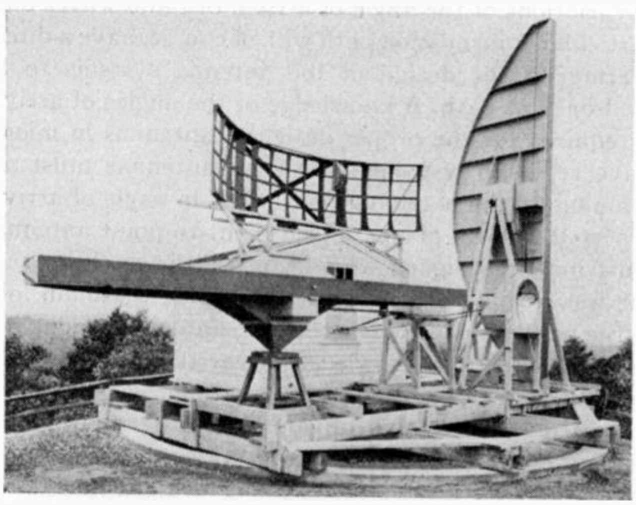

Fig. 2—Receiving antenna assembly located at Beer's Hill, New Jersey.

Fig. 3 shows the two receivers and the recorders inside the shack. The wave guides from the antenna terminate just out of view to the left of the picture. The beating oscillators and crystal first detectors for the two receivers are located at this point. By plugging into the desired guides, the outputs of any two antennas may be fed to the two receivers and simultaneously recorded.

Calibration of Scanning Antennas

The scanning antennas scan $\pm\frac{3}{4}$ of a degree. The midpoint of the scan was adjusted on our vertical scanning antenna to coincide with the angle of arrival of the direct wave from the transmitter in New York under "normal transmission" conditions.[5] It was found that the direct wave then arrived from the transmitter at the same angle as that predicted from calculations based on the actual earth geometry. The difference in angle of elevation calculated for the "true" and "$\frac{4}{3}$" earth radius was only 0.04 degree for the New York path, and this was less than the accuracy of our measurements, which are discussed below.

The physical position of the front face of the vertical antenna can be determined to about 1/100 of a degree by the use of a 20-foot-long plumb-bob line located inside the face of the antenna; but because of possible inaccuracies in building the antenna and in locating the collector at the focus, the accuracy with which the absolute position of the beam is known is believed to be somewhat lower, about 1/30 of a degree. The records can be interpreted with an accuracy of about 1/50 of a degree, which represents the relative accuracy of vertical angle measurements. The absolute accuracy is probably of the order of 1/20 of a degree.

The accuracy of angle measurement with the horizontal antenna is better than that with the vertical. The absolute position of the beam relative to an optical sight line was determined by means of a local oscillator, about two miles away, and on clear days sights were obtained on the distant transmitters during normal radio transmission conditions. The diameter of the track on which the array rotates is, as stated earlier, 25 feet, and a knife-edge pointer above the track indicates the direction the antenna beam is pointed at the center of its scan. It is not difficult to reset to a previous calibration mark to better than 1/16 inch, which means the antenna beams are normally reset to any given transmitter to better than 1/50 of a degree. Fig. 4(a) shows a calibration record made with a transmitter located at the Holmdel Laboratories 2.2 miles away (see Fig. 1). The record shows the variation in amplitude of the received signal with time as the antenna was rocked sideways (from east to west and return, etc.). The signal-amplitude scale is nearly linear. The time taken to complete a rocking cycle, from east to west and return, is 20 seconds; i.e., the separation between every second peak is exactly 20 seconds. The "on-center" part of the record was taken for the condition where the scanning antenna pointed directly at the transmitter when at the midpoint of its scanning cycle. For this condition the peaks of maximum amplitude are equispaced. The change in the record caused by setting the antenna "off" (0.05 degree and 0.10 degree) either side of the correct setting is shown on either side of center on the record. It will be noticed that, if the spacing between the amplitude peaks becomes smaller on the east swing, the signal is arriving from the east of center. The record illustrates that measurements of the separation between peaks give the angle of arrival with great accuracy, and it is the method that has been used in this work.

[5] Normal transmission conditions, for the propagation measurements given in this paper, are not distinguishable from those expected for the case of transmission through a standard atmosphere.

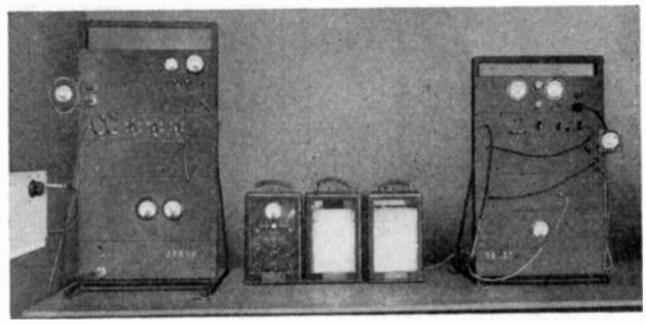

Fig. 3—Receiving sets and recording equipment at Beer's Hill.

Transmission Paths

Observations with this equipment were made on two different types of optical paths on a part-time basis through the summer of 1944. The New York path, 24.06 miles in length, was partly over water and was put in operation on June 8, 1944. The Deal path, 12.63 miles in length, was entirely over gently rolling land, and was in operation on September 1, 1944. Measurements were continued until the early part of October, 1944. The profile details of both paths are given in Fig. 5. Lines *AB* drawn from the transmitter to the receiver on the New York profile and *DB* on the Deal profile indicate the straight-line paths of the direct waves. The possible path of a reflected ray *ACB* on the New York path has also been sketched in.

Results

The ***horizontal angle of arrival*** of the received waves has not been found to deviate more than $\pm 1/10$ degree from the true bearings of the Deal or New York transmitters. There have been occasions when the horizontal angle of arrival apparently remained 1/10 degree east on the New York path for short periods, but this is very exceptional. Variations of the angle of arrival in the horizontal plane, for the most part, appear to be rapid; at times, changes of the order of 1/10 degree have taken place in the 20-second interval between adjacent sweeps of the scanning antenna. There has been no indication that this small shifting of the angle of arrival in the horizontal plane is influenced or tied in with any change that may be taking place in the arrival angle of the waves in the vertical plane. This is interesting when one

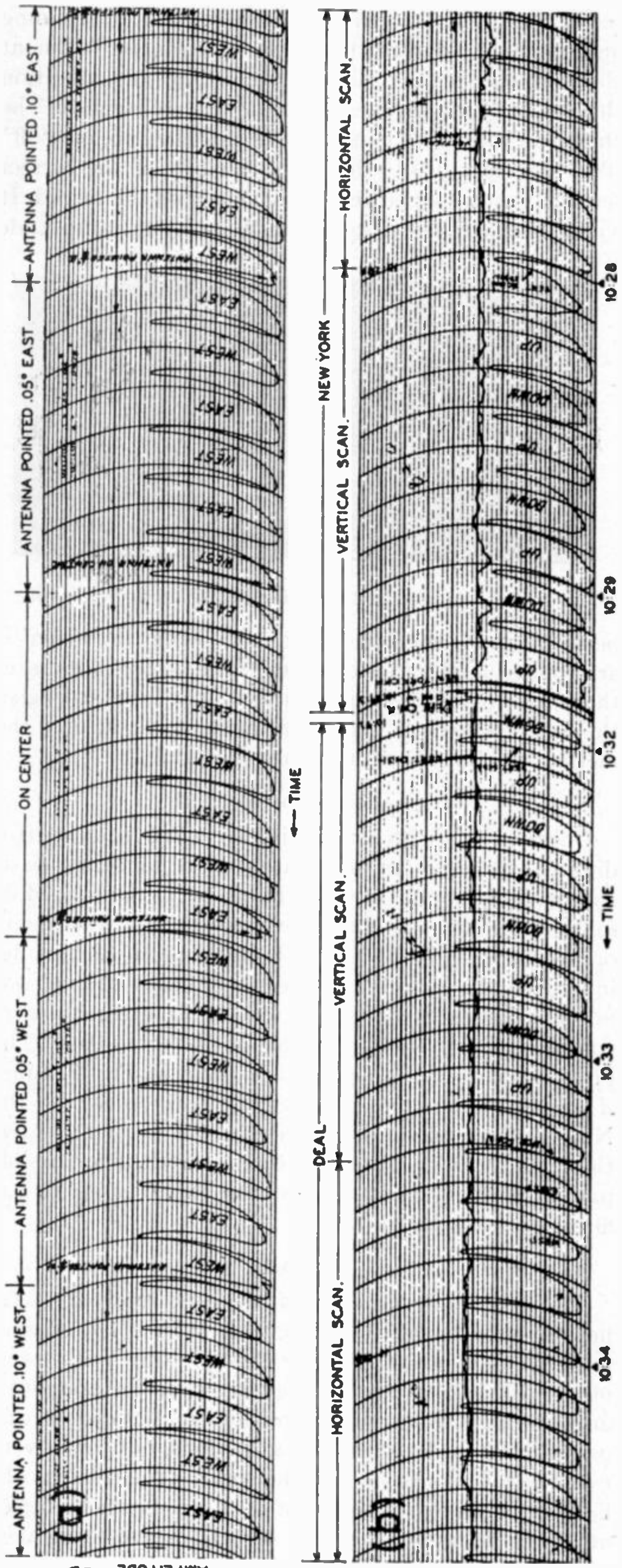

Fig. 4(a)—Calibration record: September 30, 1944. Horizontal scanning antenna. Holmdel transmitter, located 2.2 miles from Beer's Hill.

Fig. 4(b)—Normal transmission record: September 30, 1944, EWT 10:27–10:35 A.M. New York and Deal Transmitters. Weather: Cloudy. Temperature, 59 degrees. Wind, east 12 miles per hour. Visibility, 12 miles.

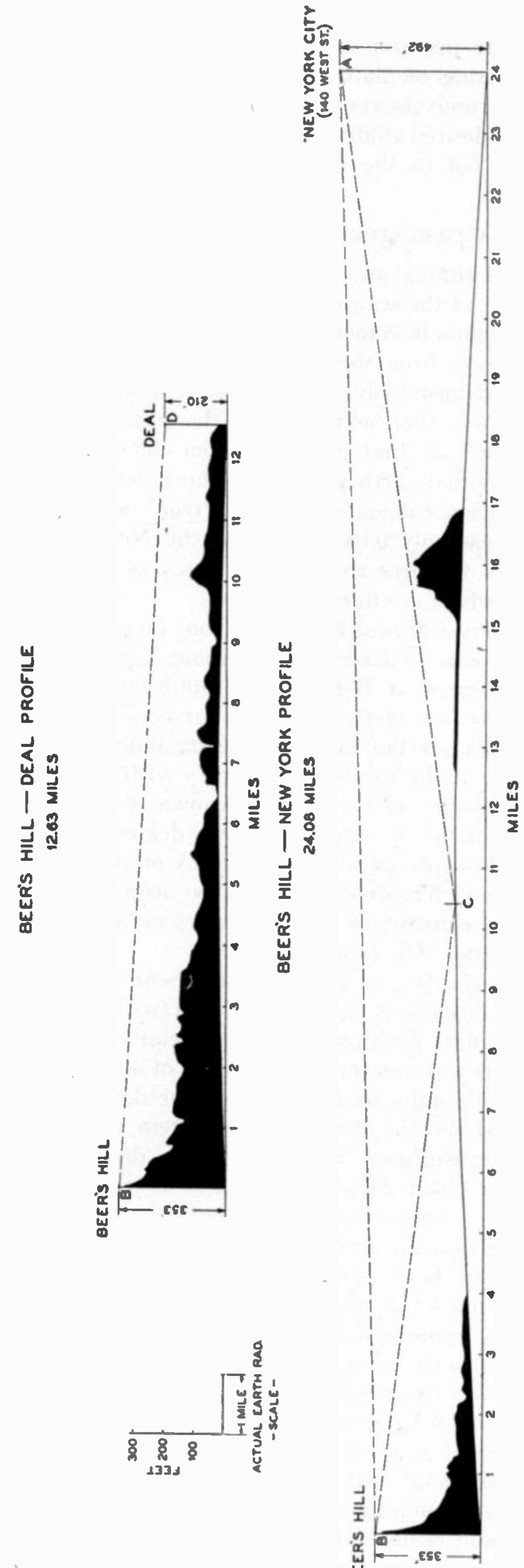

Fig. 5—Profile maps of New York–Beer's Hill and Deal–Beer's Hill paths.

considers that at times several vertical-plane paths, which will be discussed later, may be involved. It is rather encouraging that greater horizontal deviations have not been observed, because this permits, in the 3-centimeter band, the use of antennas with horizontal beams as narrow as that of the scanning antenna, $\frac{1}{3}$ of a degree, for radar and communication. However, as this work is continued, greater variations may be found to occur.

The *vertical angles of arrival* herein reported have in all cases been referred to the normal elevation angle of the distant transmitter, as discussed earlier. The records described in the following paragraphs illustrate several types of propagation that have been observed. The particular scanning antenna whose peaked output curve is being recorded is marked along the top of the record. The wavy line running the full length of some of the records is, unless otherwise marked, the simultaneous output of the $3\frac{1}{2}$-degree broad-beamed dish antenna. Other notes on the records are self-explanatory.

Normal Propagation

Fig. 4(b) shows a record obtained under typical normal propagation conditions for both the Deal and New York paths. Short samples of the horizontal and vertical scanning-antenna outputs for both transmission paths, together with the output of the broader-beamed reference dish antenna, were recorded. The record extends over a period of about 8 minutes. This time includes the time taken to turn the array from one transmitter to the other and to tune in the new signal. The output levels of the antennas and the angles of arrival are normal. By measuring the average distance between peaks on that part of the record which shows signals received from New York on the vertical scanning antenna, it is seen that the "up" and "down" parts of the scanning cycle are of equal length (distance between peaks equal). This means the signals were arriving from the normal direction of the New York transmitter in the vertical plane. The Deal portion of the record shows the vertical angle of arrival on this path to be lower than on New York by 0.11 degree, which would be expected from the geometry involved. That the angle of arrival is lower on the Deal path can be observed from the record, as the "up" parts of the scanning cycle are now longer than the "down" parts.

It will be noticed also that a slight ground-reflected wave is received from Deal and New York as the antenna is pointed down; this reflected component prevents the output level, as indicated on the recorder, from dropping to the same low level as when the antenna is pointed up. The reflection coefficient for the reflected wave path of the Deal circuit, which is entirely over land, has been measured by variable-height experiments to be only 0.18, which agrees well with the scanning patterns observed on this circuit. On the over-water New York circuit, a reflected wave is more in evidence. During normal propagation, a stronger-than-observed reflected wave might be expected on the New York circuit, since the profile map (see Fig. 5) shows that the reflection point, C, is located on the salt water of Raritan Bay. It is surmised that the proximity of the Staten Island hill, which the reflected wave path clears by less than the first Fresnel zone under normal conditions, may be the cause of the normally low amplitude of the reflected wave. However, this may not be the entire cause, as special experiments, with a portable transmitter located on the side of Staten Island toward the receiver, gave results which indicate that the effective reflection coefficient for Raritan Bay at a point such as point C in Fig. 5 is only about 0.5, and is not as high as might have been expected from measurements reported by other workers.

Fig. 4(b) shows that the horizontal angles of arrival on both the Deal and New York paths average very nearly true bearing angles, though it will be noticed that individual sweeps of the antenna do show some weaving of the angle of arrival of the signals in the horizontal plane.

Anomalous Propagation of the Reflected Wave

In contrast to the normal conditions shown by the record of Fig. 4(b), anomalous propagation of the reflected wave was occasionally observed on the New York circuit. At these times the reflected wave was characterized by stronger amplitudes and lower angles of arrival than those found during the periods of normal propagation. Such propagation produced the usual type of wave interference fading between the direct and reflected components.

Fig. 6(a) shows a sample of a record obtained when this type of propagation was in evidence (August 10, 1944, 5:00 P.M.). The reflected wave at this time has about the same amplitude as the direct wave. The scanning beam is not sharp enough to separate completely the two waves and the record becomes very interesting. At the left of the record the waves add in phase in the output of the scanning antenna and only two peaks occur per cycle. At the right of the record the waves are out of phase and four peaks occur per scanning cycle. In the broad-beamed dish antenna (wavy line) this phase relationship is reversed; i.e., in the dish, the two waves are in phase opposition at the left and produce a deep fade, and are in phase addition toward the right. The difference in location of the scanning antenna and the dish is probably the cause of this reversal in phase relationship in the two antennas. Assuming two waves with arbitrary phase and amplitude relationships, scanning patterns have been calculated that resemble the patterns shown in Fig. 6(a). These synthesized patterns indicate that the direct wave was arriving from about true transmitter direction and that the reflected wave path was about 0.4 degree below the direct wave path when the record of Fig. 6(a) was made.[6]

[6] The reflected wave from the New York transmitter, by calculation, should arrive 0.33 degree below the direct wave on a normal day. This calculation neglects any effect introduced by the presence of Staten Island.

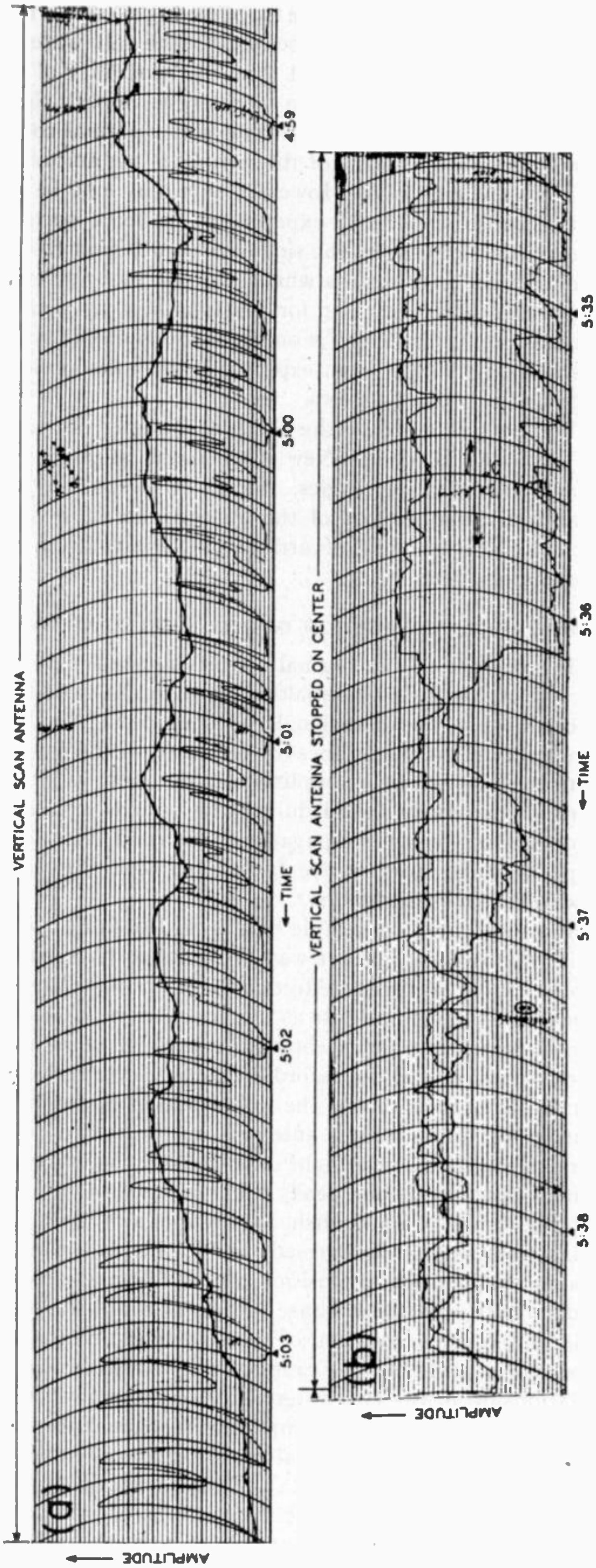

Fig. 6(a)—Record: August 10, 1944, EWT 4:58–5:04 P.M., New York transmitter. Weather: Temperature 90 degrees. Wind, southeast 2 miles per hour. Humidity high. Visibility, 4 miles.

Fig. 6(b)—Record: August 9, 1944, EWT 5:34–5:40 P.M., New York transmitter. Weather: Temperature 80 degrees; clear, sunny. Wind, southeast 5 miles per hour. Visibility, 25 miles.

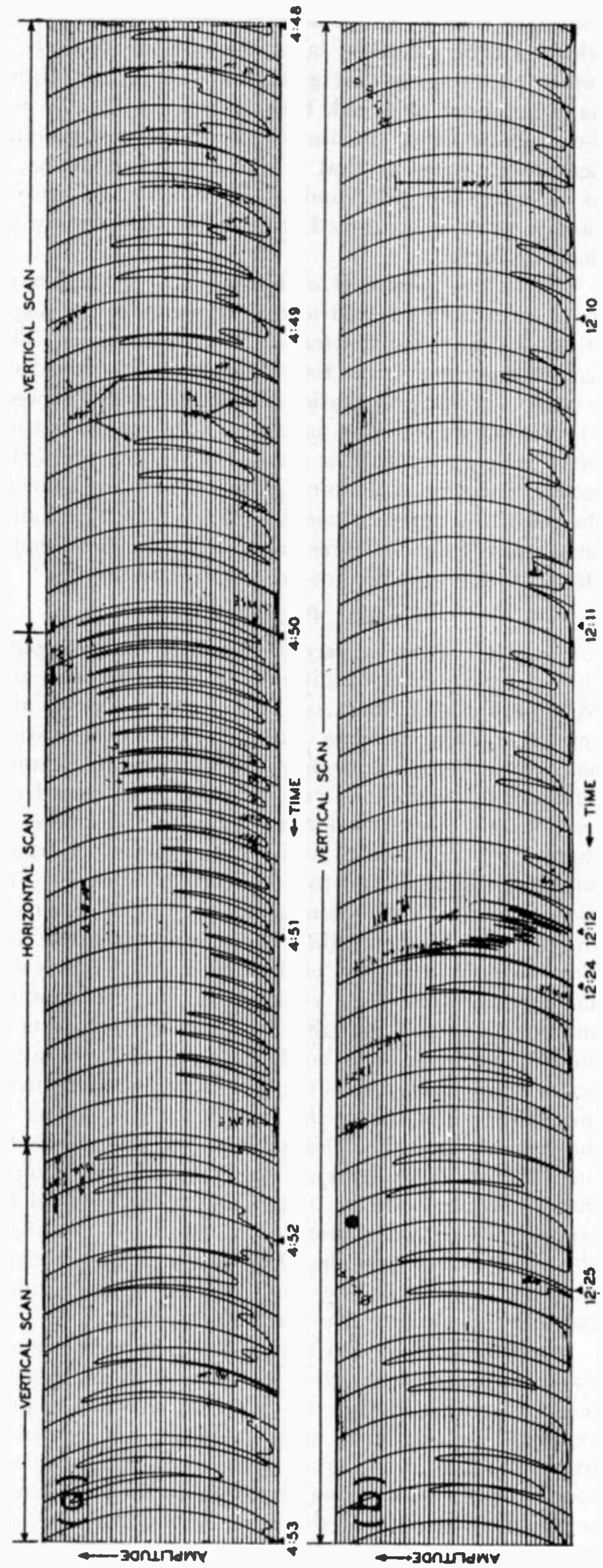

Fig. 7(a)—Record: July 7, 1944, EWT 4:48–4:53 A.M., New York transmitter. Weather: Dawn, clear. Wind, still. Temperature 70 degrees. Visibility, 1 mile, ground haze.

Fig. 7(b)—Record: July 8, 1944, EWT 12:09–12:26 A.M. New York transmitter. Weather: Clear. Temperature, 70 degrees. Wind, southeast 5 miles per hour. Visibility, 3 miles, ground haze.

Under conditions as shown in Fig. 6(a), marked improvement in fading can be accomplished by using an antenna sharp enough to reduce the amplitude of the reflected wave. A record taken the day before, under almost identical conditions to those in Fig. 6(a), is shown in Fig. 6(b) (August 9, 1944, 5:35 P.M.). Here the sharp vertical-scan antenna (upper trace) was stopped on center, so as to point toward the incoming direct wave, while the broad-beamed dish antenna (lower trace) receives the strongly reflected wave as well as the direct wave. The output of the dish antenna changes about 20 decibels, while the output of the sharp antenna varies less than 4 decibels.

The record shown in Fig. 6(a) is only one of many. One record obtained showed a reflected wave much stronger than the direct wave and arriving at an angle about 0.5 degree below the true transmitter direction. "Trapping" of the reflected wave caused by steep gradients of the dielectric constant in the atmosphere near the surface of the water is a possible cause of some of the complicated phenomena observed. So far, the measuring equipment has indicated only lower-than-normal angles of arrival of the reflected wave during anomalous transmission conditions.

Anomalous Propagation of the Direct Wave

Another type of propagation that has been observed is characterized by the direct-wave path deviating from its normal angle of arrival. Fig. 7(a) (July 7, 1944, 4:50 A.M.) shows a record made on the New York transmitter. At the time this record was made, what was presumed to be the direct wave was arriving 0.35 degree above the normal elevation angle of the transmitter, while the weaker, reflected wave was arriving about 0.40 degree below. (The higher speed scanning of the horizontal antenna is shown in center of the record.[7] The average horizontal angle of arrival at this time was 1/10 degree east.) The direct wave may have been "trapped" at this time. The record is consistent with the idea that the refraction experienced by a wave passing within a few feet of the earth's surface may be considerably different from that encountered by another wave passing some 200 feet above.

A special type of propagation, not illustrated, was observed on the Deal circuit on the foggy morning of October 14, 1944, at 10:40 A.M. The patterns for both the horizontal and vertical scanning antennas had "peaks" that indicated a normal direct wave. The levels of the "valleys," however, were about 5 decibels higher than normal. This indicated that, inside the limits of the scanning region, radiation was being received from above and below and from either side of the normal direct wave. The antenna resolution was, unfortunately, not sufficient to determine whether this unusual radiation was scattered or whether only a few distinct waves were involved.

[7] Later this scanning speed was changed, and on most of the records the scanning speed of the horizontal antenna is the same as that of the vertical.

Fig. 7(b) shows propagation on the New York circuit, where the angle of arrival of the direct wave is higher than normal and the reflected wave is practically absent. Such propagation also has been observed on the Deal circuit. The record shows an angle of arrival 0.40 degree above the normal transmitter direction. At times angles have been measured as much as 0.46 degree above the normal New York transmitter direction. Records of similar types of propagation on the Deal circuit have shown angles of elevation as high as 0.27 degree above normal. At these times the received field has changed as much as 10 decibels above and below the free-space field in a few minutes without a noticeable change in the angle of arrival or in the character of the scanning pattern. A change of 10 decibels in signal level is shown on the record of Fig. 7(b). Near the center of the record the vertical scanning antenna was stopped at the angle giving maximum signal output and the recorders were run for about 12 minutes at slow speed. The scanning was then resumed, and the record shows that the angle of arrival was the same as before the change in signal level. It is not known how often these conditions existed during the summer. They have been observed only during the calm, cool hours of darkness following a hot summer day; relatively few all-night observations were made. So far, excluding cases where attenuation was caused by rain or snow, deep fades of the direct wave have always been accompanied by higher-than-normal angles of arrival.

The kind of propagation illustrated in Fig. 7(b) will have an important effect on radars and microwave repeater circuits. The results show that low-elevation radar directions may be in error by $\frac{1}{2}$ degree in the 3-centimeter band and that the beam of our vertical scanning antenna is too narrow for point-to-point systems, when it is left in a fixed position. It is believed that fixed, sharp-beamed point-to-point antennas should be tilted upwards slightly, since, to date, the angle of arrival of the direct wave has not been found to be below the true transmitter direction.[8] On the basis of the observations, a 7-foot vertical antenna dimension, with the antenna pointed up 0.15 degree from the normal angle of arrival, would have been satisfactory for the 3-centimeter New York circuit during the summer of 1944.

There still remains a good deal of work to be done on methods of overcoming fading associated with this type of propagation. Possibly diversity reception with antennas at different heights or at different locations along the ground may prove fruitful.

Polarization Effects

As was stated earlier, the transmitters were set to radiate waves polarized at 45 degrees so that antennas that receive only horizontal or vertical polarization could be used at the receiver. The vertical scanning

[8] Meteorologists working on other radio paths have observed conditions which would indicate that lower-than-normal angles of arrival may also be possible.

antenna is designed to accept only horizontally polarized waves, while the horizontal scanning antenna accepts only vertically polarized waves. Therefore it is important to know whether or not the received signals arrive at the same polarizations as transmitted, and whether or not the fading on the two polarizations is the same. These questions were answered by the use of the reference dish antenna which could be rapidly changed

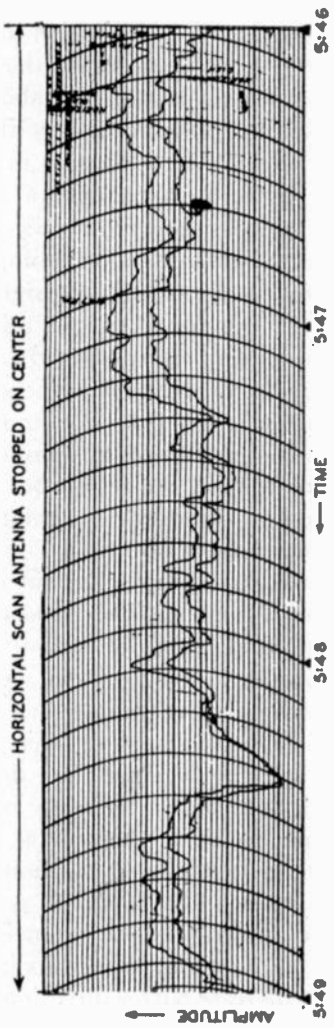

Fig. 8—Record: August 9, 1944, EWT 5:46–5:51 P.M. New York transmitter. Weather: Clear. Temperature, 78 degrees. Low humidity. Wind, northwest, 8 miles per hour. Visibility, 5 miles.

from the +45-degree polarization transmitted to the −45-degree not transmitted. It was found that, even under disturbed conditions, this change resulted in more than a 20-decibel decrease in signal, which means that the opposed polarization is at least this far down at all times. Furthermore, no important differences in fading have so far been found between waves of opposite polarization. The record reproduced in Fig. 8 (August 9, 1944, 5:45 P.M.), shows the outputs of the horizontally polarized dish antenna (lower trace) and the vertically polarized horizontal scanning antenna (upper trace) fading together. From this and other records it was concluded that no important difference exists between horizontally and vertically polarized waves in the 3-centimeter band over paths of the type used in this work.

3- and 30-Centimeter-Band Comparisons

Early in September, 1944, a 30-centimeter-band transmitter was added to the New York circuit and a few comparisons of fading on this circuit and on the regular 3-centimeter-band circuit were made.

It was found that, in general, the fading on the 30-centimeter circuit was less than on the 3-centimeter circuit. The greatest difference observed between the two was on September 27, 1944, during a sunset-period observation. A record covering one hour between 5:30 and 6:45 P.M. Eastern War Time shows that the New York 3-centimeter-band circuit using a 28-inch dish antenna suffered many 15- to 19-decibel field changes, while the 30-centimeter-band circuit showed only one 4-decibel change in field. The 3-centimeter fading was rapid at the time and was apparently caused by wave interference.

Rain Effects

No particular study has been made of rain effects, but it may be mentioned that rain has affected the transmission on both of our 3-centimeter-band paths in varying degrees, depending on the magnitude of the downfall. Light rains, in general, have had no noticeable effect, while very heavy downpours have caused as much as 8/10-decibel attenuation per mile of path length. It is very difficult for us to know what conditions of rainfall may have existed over the full length of any particular path at any particular time, but the above figures can be presented as the maximum values of attenuation that have been observed on our paths. One-half inch of rain was reported by the New York Weather Bureau for an hour interval covering one of the periods when 8/10-decibel-per-mile attenuation was observed.

Observations have been made on the 30-centimeter circuit during periods of heavy rainfall and, so far, no noticeable attenuation because of rain has been observed.

Concluding Remarks

The angle-of-arrival measurements reported in this paper cover only the results obtained from part-time observations on two particular microwave circuits. Similar results may or may not be observed in microwave circuits which are installed at locations where the terrain and meteorological conditions may be quite different. In summarizing the results obtained, the following concluding remarks are significant.

The angle of arrival of microwaves has been found to vary in both the horizontal and the vertical planes.

Vertical-plane variations have been found to be the more common, with the angle of elevation of the received signal at times deviating from the normal direction of the transmitter by as much as ½ degree.

Horizontal-angle deviations have been found to be present less frequently than those in the vertical plane and the magnitude of the deviations has been found to be much smaller. No deviation greater than 1/10 degree from the true bearing of the transmitter has been recorded.

From the above it is seen that radars designed to measure the angle of elevation of targets may be subject to occasional errors of the order of ½ degree when the angle of elevation is small.

If antennas for microwave repeater links are not made "steerable," some allowance must be made in their design for variation in the angle of arrival of the received signals.

In regard to the fading improvements possible with narrow-beamed antennas, it will be recalled that in the case of the New York path, where a strong water-reflected component was at times received, the large 20-foot-aperture, narrow-beamed antenna gave a considerable improvement in fading over that experienced with a small broad-beamed dish antenna. This result indicates that two small antennas separated by 20 feet might be expected to give useful space-diversity effects on this path.

Finally, there is evidence that at times during the course of this work our ⅓-degree beam-width scanning antennas were not sufficiently sharp to separate all the components of the radiation arriving at the receiving point. Future measuring work on microwave angles of arrival would probably be greatly benefited by making use of antennas with beam widths several times narrower than those of our present scanners.

Further Observations of the Angle of Arrival of Microwaves*

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Summary—**Microwave propagation measurements made in the summer of 1945 are described. This work, a continuation of the 1944 work reported elsewhere in this issue of the PROCEEDINGS OF THE I.R.E. AND WAVES AND ELECTRONS, was characterized by the use of an antenna with a beam width of 0.12 degree for angle-of-arrival measurements and by observations of multiple-path transmission.**

A PAPER appearing in this issue of the PROCEEDINGS[1] describes a method of measuring the angle of arrival of microwaves and gives some data obtained during the summer of 1944 at a wavelength of 3.25 centimeters using parabolic-reflector-type antennas with beam widths of about ⅓ degree (20-foot apertures). Occasionally, during this work, it was observed that antennas with still sharper beam widths were needed to separate in angle the components of the received field. Since the beam width of an antenna is inversely proportional to the linear dimension of its aperture but directly proportional to the operating wavelength, it was decided to build an antenna with a 20-foot aperture but designed to operate at a wavelength of 1.25 centimeters, and thus obtain an antenna with about two-and-one-half times sharper beam. This note describes that antenna and summarizes the results of observations made in the summer of 1945.

The metal-lens[2] type of antenna construction was chosen for the new antenna because the physical tolerances required could be realized more easily than with a parabolic-reflector-type antenna of the same size designed for a wavelength as short as 1.25 centimeters. The operation of a metal-lens antenna depends on the fact that a wave traveling between conducting plates parallel to the electric field and spaced more than a half wavelength, as in a wave guide, has a phase velocity greater than the wave in free space. By properly shaping the profile of a structure consisting of a number of such parallel plates, a plane wave can be brought to a focus. In Fig. 1, the lens antenna (at the extreme right

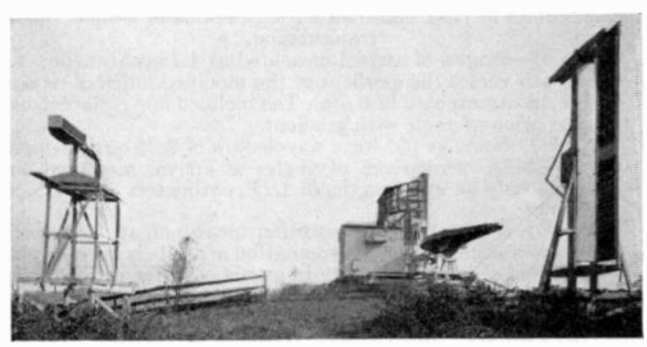

Fig. 1—Photograph of receiving antennas at Beer's Hill, N. J. The lens antenna, in the right foreground, has a beam width of 0.12 degree and was used for angle-of-arrival measurements at 1 25 centimeters wavelength. The antennas used at 3.25 centimeters and the receiving shack are in the background.

of the picture) consists of seventy vertical parallel plates held to a spacing of about one-third inch by means of horizontal spacing strips. The profile is "stepped back" at points where the required phase corrections are multiples of 360 degrees, thus keeping the lens thickness at a minimum. The lens, 20 feet high and 2 feet wide, in combination with the collector antenna at the focal distance (48.6 feet to the rear of the lens), has a beam width at half-power points of 0.12 degree in the plane perpendicular to its short dimension and 1.2 degrees in the plane perpendicular to its long dimension. The minor lobes are about 25 decibels down from the major lobe. The beam of this antenna is scanned, sinusoidally, through an angle of ±0.75

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[1] William M. Sharpless, "Measurement of the angle of arrival of microwaves," PROC. I.R.E. this issue, pp. 837–845.

[2] W. E. Kock, "Metal-lens antennas," PROC. I.R.E., this issue, pp. 828–836.

degree in the vertical plane by moving the lens 7⅝ inches up and down from its central position by means of a motor-driven connecting-rod mechanism, not visible in the photograph. By rotating the lens assembly and the collector antenna through 90 degrees, the system is used for scanning in the horizontal plane.

Using this antenna and a broad-beam (2.75 degrees) parabolic-reflector-type antenna at 1.25 centimeters, and also the 3.25-centimeter equipment described in

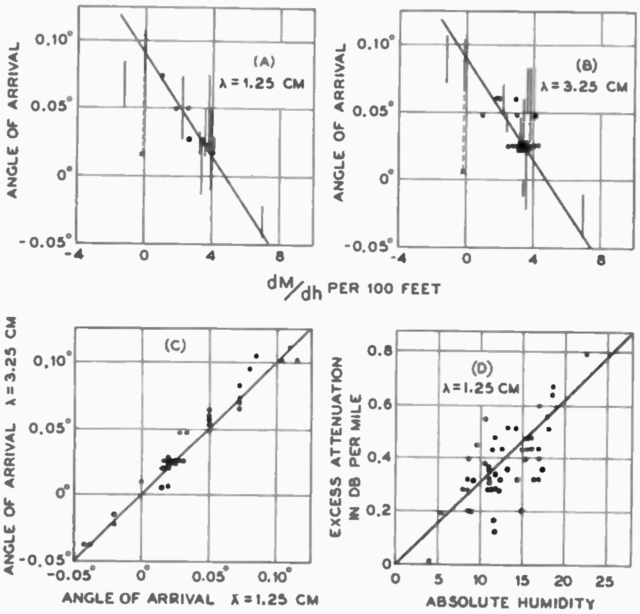

Fig. 2.—Plots of data obtained during periods of simple, one-path transmission.

Plot (A)—Angles of arrival measured at 1.25 centimeters wavelength versus the gradient of the modified index of refraction of the atmosphere (dM/dh). The inclined line is the calculated variation of angle with gradient.

Plot (B)—Same as (A) for a wavelength of 3.25 centimeters.

Plot (C)—A comparison of angles of arrival measured simultaneously at wavelengths of 1.25 centimeters and 3.25 centimeters.

Plot (D)—Atmospheric absorption measured at 1.25 centimeters wavelength; excess attenuation in decibels per mile plotted against absolute humidity in grams of water vapor per cubic meter.

the previously mentioned paper,[1] part-time measurements of angle of arrival and signal level were made during the summer of 1945 over the Deal–Beer's Hill path; a 12.63-mile overland path for which the line of sight clears the average ground level by about 155 feet (see Figs. 1 and 5, *loc. cit.*). Angle-of-arrival measurements were made in the manner described in the above paper, i.e., by observing the spacing between the signal peaks recorded on a continuously moving chart as the beam of the antenna was scanned through the incoming waves at a rate of three scanning cycles per minute.

Our radio data have been supplemented by meteorological data in the form of *M*-curves[3] which were furnished us through the co-operation of the NDRC Committee on Propagation, represented by Captain W. E. Gordon of the Army Air Forces and A. T. Waterman, Jr., of the Wave Propagation Group, Columbia University. These curves, six for each day, were intended to be representative for the path, and were synthesized from low-level soundings made by balloon at the Holmdel Laboratory (see map, Fig. 1, *loc. cit.*) and on a 400-foot radar tower about 1½ miles south of our transmitting site at Deal.

From about the middle of July to the end of September, observations were made during periods ranging from ½ hour to 8 hours in length on most of the days and on twenty nights when clear, relatively calm weather conditions suggested the possibility of anomalous propagation. The major results are described below.

1. In the horizontal plane, angular deviations from the line of sight were usually absent and were never observed to be larger than 0.03 degree.

2. In the vertical plane, except for two nights when multiple-path transmission was present, the angle of arrival varied from -0.04 degree to $+0.11$ degree, relative to the line of sight, on both wavelengths. Most of the deviations occurred during the nighttime hours. As was to be expected from simple ray theory, there was a correlation between the angle of arrival and the gradient of the modified index of refraction (see plots (A) and (B) of Fig. 2). In these plots measured angles of arrival or, as shown by the vertical lines, the range in angle during the observation period, are plotted against refractive-index gradients obtained from the *M*-curves most nearly corresponding in time with the radio measurements, usually within two hours. The inclined lines show the calculated variation of angle with gradient.

The scattering of the data in plots (A) and (B) may be partly the result of errors of measurement and partly because of the fact that the radio and meteorological data do not always correspond in time. On the night of September 12–13, the angle of arrival for both wavelengths varied over a small range during the four-hour observation period, with the exception of a short interval of time when a much different angle was observed. This angle is indicated on the plots by a cross which is connected by a dotted line with the solid line representing the range in angle measured during the major part of the period. *M*-curves were available for only the beginning and end of the period and both of these indicated an *M*-gradient of zero.

3. Angles measured simultaneously at 1.25 centimeters and at 3.25 centimeters agreed quite well, as shown in plot (C) of Fig. 2, which is also for periods of simple one-path transmission.

4. Fading ranges observed with the broad-beam antennas were usually less than 6 decibels, except on the nights of multiple-path transmission. Scintillation fading (rapid fluctuations of from ½ to 1½ decibels about a steady average signal level) was usually present during the daytime and on windy nights, and was more severe at 1.25 centimeters than at 3.25 centimeters. Observations made at 1.25 centimeters showed that the scintillation fading was generally less on the large narrow-beam scanning antenna (held in a fixed position for this test)

[3] Modified index of refraction of the atmosphere plotted against height above ground.

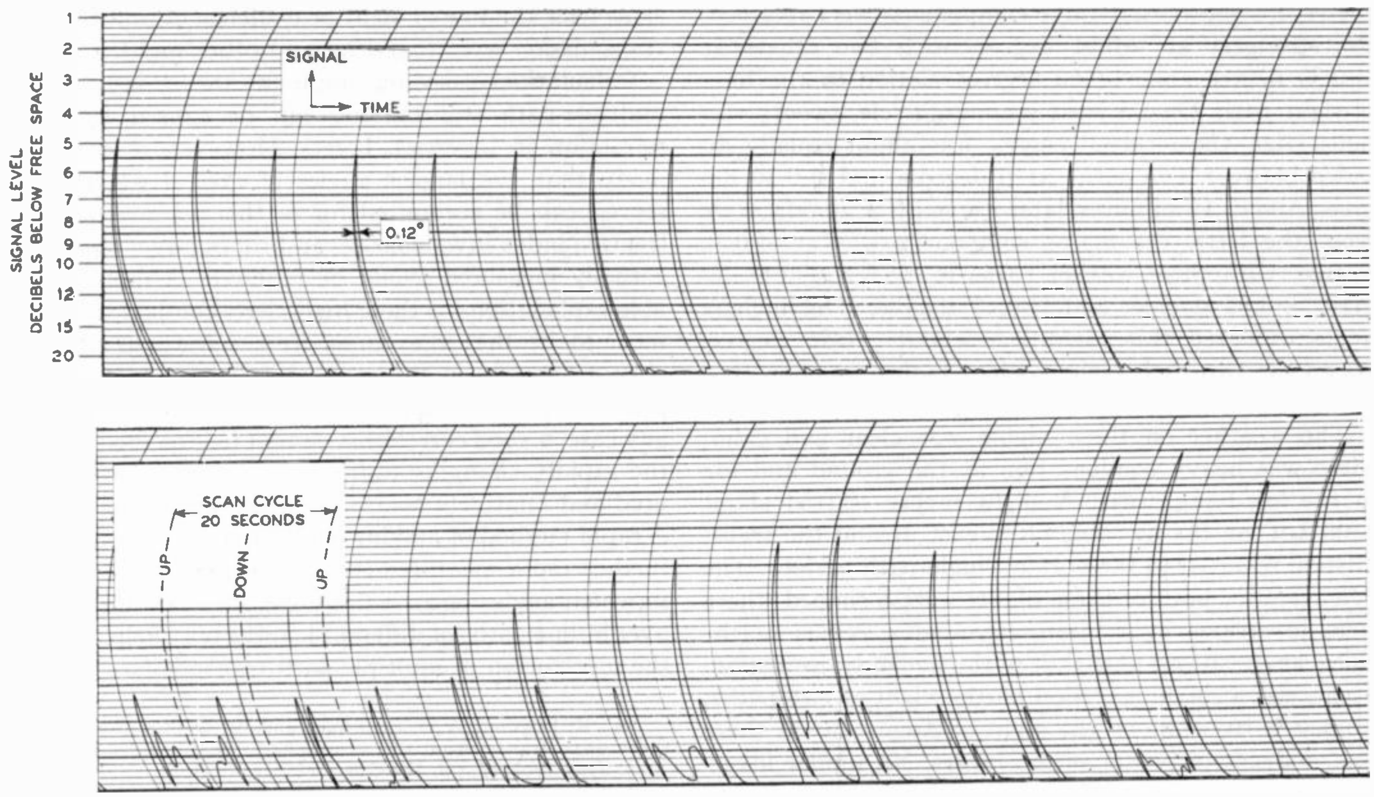

Fig. 3—Sample scanning records for 1.25-centimeter wavelength.
Upper chart—Normal day scanning record. Lower chart—Example of multiple-path transmission.

than on the small broad-beam antenna; this observation is analogous, perhaps, to the optical one in which star scintillation is less when viewed through a large telescope than when seen by the unaided eye.

5. The 1.25-centimeter signal was "washed out" by rainstorms and was affected in mean amplitude by day-to-day variations in the absolute humidity. Plot *D* of Fig. 2 shows atmospheric absorption, expressed in decibels per mile in excess of free-space attenuation, plotted against absolute humidity (grams of water vapor per cubic meter) calculated from measurements of air temperature and relative humidity at the Beer's Hill receiving site. The solid line is the theoretical relation of Dr. J. H. Van Vleck for the case of the absorption line centered at a wavelength of 1.33 centimeters.[4] A typical value of absorption at 1.25 centimeters for summertime in this locality is about 0.4 decibel per mile. Heavy rains had an effect on the 3.25-centimeter signal, but attenuation effects due to water-vapor absorption were too small to be observed.

6. Multiple-path transmission was observed on two nights, August 9–10 and August 30–31, when the scanning records showed that the received signal consisted of several components arriving simultaneously at different angles. The angles quoted below are for the 1.25-centimeter wavelength, since the 3.25-centimeter antenna with its ⅓-degree beam width was unable, most of the time, to resolve the components; at times there was evidence of components so closely spaced in angle that even the 0.12 degree beam of the 1.25-centimeter antenna could not resolve them.

Beginning about 2:30 A.M. on August 10 and still continuing at 6:30 A.M., when observations were discontinued, two transmission paths were present much of the time. One of these was apparently the "normal" or daytime path; the angle of arrival and the signal level of this component were, for the most part, nearly normal. The other component arrived at an angle which varied from 0.21 to 0.46 degree above the line of sight and also varied in amplitude, sometimes very rapidly, over a range of 20 decibels. Wave interference between these components caused severe fading on the broad-beam antennas which would accept both components. The signal-level variation on both wavelengths was from about 20 decibels below to 10 decibels above the free-space level, but otherwise there was little similarity in the fading records for the two wavelengths.

On the night of August 30–31, from about 10:30 P.M. to 4:00 A.M., two, three, and, at times, four separate transmission paths were observed. All of these varied in angle of arrival and all had large, rapid variations in signal level; the normal or daytime path sometimes was missing. A short section of the scanning record for this night is shown at the bottom of Fig. 3, which shows also, for comparison, a sample record which is typical of normal day scanning. The lines marked "up" and "down" indicate the points on the record for which the antenna was at the top or bottom, respectively, of its scanning cycle. At the extreme left of the bottom chart

[4] From the paper, "The atmospheric absorption of microwaves," presented by Dr. Van Vleck at the Cambridge Meeting of the American Physical Society, April 26, 1946.

the record shows that three components were received: the strongest at +0.01 degree, with two others at +0.30 degree and +0.62 degree relative to the line-of-sight path. On the next scanning cycle, twenty seconds later, the received energy was about equally divided between two paths at 0 degrees and +0.30 degree. About 1½ minutes later (seventh scanning cycle from the left), the major component was at +0.30 degree, with three weaker paths in evidence at 0 degree, +0.54 degree, and +0.69 degree. The highest angle observed this night was about +0.75 degree. As on the two-path night, violent fading was observed on the broad-beam antennas.

The weather on these nights was clear and calm; there was heavy condensation at the ground and fog in the low-lying areas. A slight breeze started about 4:00 A.M. on the morning of August 31 and the transmission reverted to the normal single-path variety. The M-curves for both of these nights were S-shaped; there were inversions in the refractive-index versus height curve at elevations near that of the line of transmission. There was a single inversion on the night of two paths, August 9–10, while on the night of August 30–31 there was evidence of two inversion layers. No similar inversions near the line of sight or evidence of multiple-path transmission were found on any other night.

Calculations based on simple ray theory indicate that multiple-path transmission can be caused by super-refraction in inversion layers. However, it seems unlikely that the largest angles of arrival we have observed can be accounted for in this manner, since refractive index inversions several times larger than those actually measured would be required. A more reasonable explanation for these high-angle components would seem to be that they arise from reflections at small, abrupt changes in the refractive index which may be present at the boundaries of the inversion layers.[5] In any case, a good correlation cannot be expected between the rapidly changing radio data and the slowly measured and relatively coarse-grained meteorological data. A rapid method of making continuous air soundings and further radio measurements is needed. An experiment in which angles of arrival are measured simultaneously over in-line paths of different lengths may help to clarify the mechanism of multiple-path transmission.

[5] C. R. Englund, A. B. Crawford, and W. W. Mumford, "Ultra-short wave transmission and atmospheric irregularities," *Bell Sys. Tech. Jour.*, vol. 17, pp. 489–519, October, 1938.

The Cathode Follower Driven by a Rectangular Voltage Wave*

MALCOLM S. McILROY†

Summary—**A rectangular voltage wave is often transmitted from a high-impedance source to a low-impedance load through resistance-capacitance coupling and a cathode follower. The position of the grid-return tap on the cathode resistor determines, for any applied voltage wave form, whether the output voltage wave is linearly related to the input voltage wave or is affected by cutoff or by overdriving. This paper presents methods for determining the operating condition that applies and derives expressions for the circuit voltages, subject to stated assumptions.**

General Analysis

The CATHODE follower is often used in combination with a resistance-capacitance coupling circuit to transmit a periodic rectangular voltage wave from a high-impedance source circuit to a load circuit having relatively low impedance.[1] The voltage wave is transmitted with a gain less than one and without polarity inversion. Fig. 1 illustrates this circuit and shows the grid-return resistor R_g connected, or "returned," to a tap on the cathode resistor R_k. The numerical value of R_k is intended to represent the parallel combination of the resistance in the cathode circuit and the resistance of a load. The quantity α, representing the fraction of the resistance R_k which is between the grid-return tap and ground, may have any value from zero to one. No grid current flows in the series clipping resistor R_s when the grid voltage e_c is negative. Since the resistor R_s limits the flow of grid current when e_c is positive, the magnitude of e_c is then negligible compared with other circuit voltages.

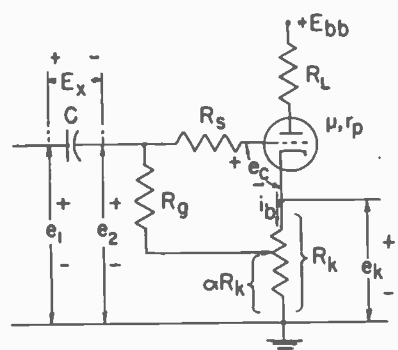

Fig. 1—Cathode follower with resistance-capacitance coupling and variable grid-return tap on the cathode resistor.

The tap position of the grid-return resistor as given by the fraction α affects the average value of the voltage e_2 and hence the average value of the output voltage e_k and the limits of linear operation. In the discussion which follows an analysis is made of the relations that

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[1] Walther Richter, "Cathode follower circuits," *Electronics*, vol. 16, pp. 112–117, and 312; November, 1943.

exist in the circuit, including the influence of the location of the grid-return tap, when e_1, the input voltage to the circuit, has a rectangular wave form. The electric-current relations presented here are subject to the following four assumptions:

(1) The time constants R_gC and R_sC are sufficiently large so that, under steady operating conditions with the periodic rectangular voltage wave applied, the voltage E_x across the capacitor C is substantially constant.

(2) The grid-return resistor R_g is very large, and R_s is large compared with the cathode resistor R_k.

(3) The input voltage e_1 is the actual voltage present when the circuit is in operation.

(4) Interelectrode capacitances, stray capacitances, and load capacitance do not significantly affect the voltages in the circuit.

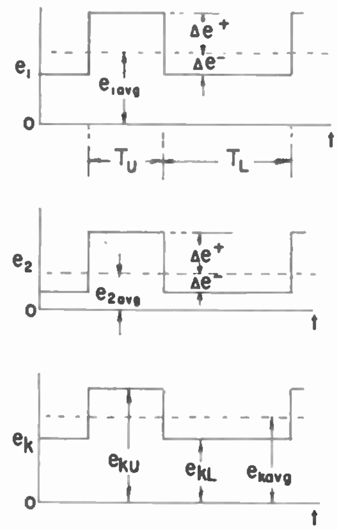


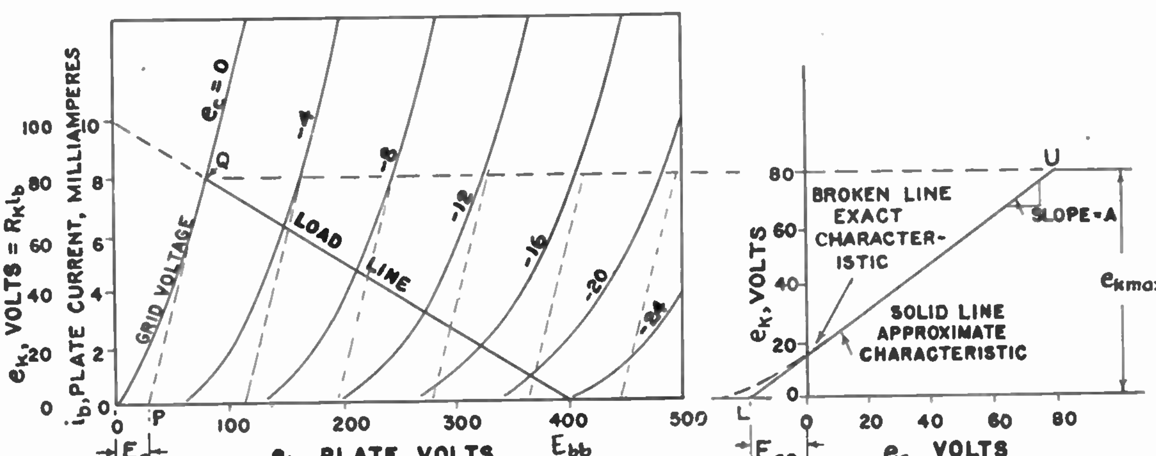
Fig. 2—Wave forms of voltages indicated in Fig. 1.

Since the capacitor voltage E_x is assumed to be constant, the voltages e_1 and e_2 are exactly alike except for their average values. Therefore the two arithmetical differences, Δe^+ and Δe^- in Fig. 2, between the actual values and the average values, apply equally to e_1 and e_2. If the differences Δe^+ and Δe^- are respectively added to and subtracted from a known average value of e_2, the wave form of the voltage e_2 is completely defined. The wave form of the output voltage e_k may be found from the graphical construction of Fig. 3 for any known voltage e_2. The plate load line is drawn, intersecting the plate-voltage axis at E_{bb} and the plate-current axis at $E_{bb}/(R_k+R_L)$. In the example of Fig. 3, the values used for R_k and R_L are 10,000 ohms and 30,000 ohms, respectively. An ordinate scale is added to represent the output voltage, with values $e_k=R_ki_b$ as shown. For several points on the load line, corresponding values of e_k and e_c and their sum e_2 are listed and used to plot a graph of e_k versus e_2, as in the broken line of Fig. 3 (b).

Since the resistor R_s prevents the existence of significant positive values of e_c, the output voltage cannot exceed its value at the point Q in Fig. 3(a), where the load line intersects the curve for $e_c=0$. Therefore, for all values of e_2 to the right of point U in Fig. 3(b), the output voltage is very nearly constant.

Because the curves which represent equal increments of grid voltage in the tube characteristics do not intersect the load line at equal distances for low values of plate current, the lower end of the broken-line exact characteristic in Fig. 3(b) is curved. In analytical work, results sufficiently accurate for most purposes are achieved if the lines of constant grid voltage in Fig. 3(a) are represented by equally spaced straight lines parallel to the line QP drawn tangent to the $e_c=0$ curve at point Q. If the graphical projection previously described is then repeated, the characteristic in Fig. 3(b) is the solid straight line LU, which differs slightly from the exact characteristic for low values of the output voltage e_k. The intersection distance LO on the abscissa axis of Fig. 3(b) is the magnitude E_{co} of the cutoff grid voltage to be used in the linear-approximation method of analysis, since e_c and e_2 are equal at cutoff. The value of E_{co} may be computed without preparation of a graph by employing the reasoning which follows.

In Fig. 3(a) let E_0 represent the plate voltage OP at the intersection with the abscissa axis of the line QP. The change in plate voltage for zero plate current between $e_c=0$ and e_c at cutoff is then $E_{bb}-E_0$. The change



(a) (b)

Fig. 3—(a) Characteristics of triode employed in Fig. 1. (b) Relation between e_k and e_2.

in grid voltage for the same operating range is E_{co}. Hence the ratio $(E_{bb}-E_0)/E_{co}$ is equal to μ, the amplification factor, and the value of E_{co} is

$$E_{co} = \frac{E_{bb} - E_0}{\mu}. \tag{1}$$

The slope of the solid line LU in Fig. 3(b) is the amplification A, defined by the expression[2]

$$A = \frac{\mu}{\mu + 1 + \dfrac{r_p + R_L}{R_k}} \tag{2}$$

in which r_p is the dynamic plate resistance of the triode at the point Q.

The relation between e_2, and e_k, as shown in Fig. 3(b), may be expressed as

$$e_k = A(e_2 + E_{co}). \tag{3}$$

During the period T_U, when e_1 has its upper value $e_{1avg}+\Delta e^+$ (see Fig. 2), grid current may flow; during the period T_L, when e_1 has its lower value $e_{1avg}-\Delta e^-$, the tube may be cut off. The larger the value of the fraction α, the higher becomes the voltage on the right-hand plate of the capacitor and the more likely is grid current to flow during the period T_U. The smaller the value of α, the lower is the voltage on the right-hand plate and the more likely is the tube to cut off during the period T_L.

The possible combinations of input wave form and of the fraction α may be grouped under four operating conditions, which are considered separately in the following paragraphs. The four conditions are:

1. Grid current never flows. Plate current is never cut off.
2. Grid current never flows. Plate current is cut off during period T_L.
3. Grid current flows in period T_U. Plate current is never cut off.
4. Grid current flows in period T_U. Plate current is cut off during period T_L.

Condition 1. The grid-to-cathode voltage e_c is always negative, and the tube plate current is never cut off.

With the grid-to-cathode voltage always negative between zero and the cut-off value E_{co}, the cathode follower operates as a linear circuit having the input and output voltage wave forms shown in Fig. 2. Since no grid current flows, the average current through R_g is zero. Therefore,

$$e_{2avg} = \alpha e_{kavg}. \tag{4}$$

Since operation in condition 1 is confined to the straight line LU of Fig. 3(b), equation (3) applies to average values as well as to instantaneous values. Therefore,

$$e_{kavg} = A(e_{2avg} + E_{co}). \tag{5}$$

A simultaneous solution of (4) and (5) determines the values of the unknown voltages:

$$e_{2avg} = \frac{\alpha A}{1 - \alpha A} E_{co} \tag{6}$$

$$e_{kavg} = \frac{A}{1 - \alpha A} E_{co}. \tag{7}$$

The upper and lower values of output voltage e_k may be found, respectively, from

$$e_{kU} = e_{kavg} + A\Delta e^+ \tag{8}$$

$$e_{kL} = e_{kavg} - A\Delta e^- \tag{9}$$

and the capacitor voltage is

$$E_z = e_{1avg} - e_{2avg}. \tag{10}$$

If Δe^- equals the difference in voltage between e_{2avg} and $-E_{co}$ (see Fig. 3(b)), the tube cuts off. Then

$$\Delta e^- = e_{2avg} + E_{co}$$

$$= \frac{\alpha A}{1 - \alpha A} E_{co} + E_{co}$$

$$\Delta e^- = \frac{1}{1 - \alpha A} E_{co}. \tag{11}$$

Therefore the lower limit α_{L_1} of the value of α below which condition 1 does not apply is

$$\alpha_{L_1} = \frac{1}{A}\left(1 - \frac{E_{co}}{\Delta e^-}\right). \tag{12}$$

If the value of α_{L_1} found from (12) is negative, plate-current cutoff does not occur for any position of the tap on R_k.

The voltages e_k and e_2 are equal at the point U in Fig. 3(b), where grid current starts to flow. Therefore, from the geometry of the figure,

$$A = \frac{e_{kmax}}{e_{kmax} + E_{co}} \tag{13}$$

and

$$e_{kmax} = \frac{AE_{co}}{1 - A}. \tag{14}$$

If Δe^+ equals the difference in voltage between e_{kmax} and e_{2avg}, grid current flows. Then

$$\Delta e^+ = \frac{AE_{co}}{1 - A} - e_{2avg}. \tag{15}$$

If the value of e_{2avg} from (6) is substituted in (15), and (15) is solved for the upper limit α_{U_1} of the value of α above which condition 1 does not apply, the result is

$$\alpha_{U_1} = \frac{E_{co} - \dfrac{1 - A}{A}\Delta e^+}{E_{co} - (1 - A)\Delta e^+}. \tag{16}$$

Condition 2. The grid-to-cathode voltage is always negative, but the tube plate current is cut off during the period T_L of lower output voltage.

If the value of the tap ratio on the cathode resistor is less than α_{L_1} as defined by (12), the plate current is cut off during the period T_L. Since the output voltage is zero during the period T_L, the average value of the output voltage is

[2] Electrical Engineering Staff, Massachusetts Institute of Technology, "Applied Electronics," John Wiley and Sons, Inc., New York, N. Y., 1943, p. 537, equation 177.

$$e_{k\,avg} = \frac{T_U}{T_L + T_U} e_{kU}. \tag{17}$$

Since no grid current flows,

$$e_{2avg} = \alpha e_{k\,avg} = \frac{\alpha T_U}{T_L + T_U} e_{kU}. \tag{18}$$

The upper value of e_k may be found from the slope-form equation of the line in Fig. 3(b).

$$e_{kU} = A\left[e_{2avg} + \Delta e^+ + E_{co}\right]. \tag{19}$$

Equations (18) and (19) are solved simultaneously for the unknown value of e_{2avg}:

$$e_{2avg} = \frac{\alpha A\left[\Delta e^+ + E_{co}\right]}{1 - \alpha A + \dfrac{\Delta e^+}{\Delta e^-}}. \tag{20}$$

As in condition 1, (15) establishes the upper limit of Δe^+ for condition 2. If the value of e_{2avg}, from (20) is substituted in (15), the upper limit α_{U_2} of the value of α for condition 2 is

$$\alpha_{U_2} = \left(1 + \frac{\Delta e^+}{\Delta e^-}\right)\left[1 - \frac{(1 - A)\Delta e^+}{AE_{co}}\right]. \tag{21}$$

Condition 3. Grid current flows during the period of higher input voltage, and the tube is never cut off.

If the value of α exceeds α_{U_1} as found in (16), grid current flows during the period T_U. The upper value of the output voltage e_{kmax} is found from (14). The lower value of the output voltage for condition 3 is found from Fig. 3(b)

$$e_{kL} = A(e_{2avg} + E_{co} - \Delta e^-). \tag{22}$$

The charge gained by the coupling capacitor C during period T_U is equal to the charge lost during period T_L. The charging current during period T_U is the sum of the currents through resistors R_s and R_g. During period T_L the entire discharge current flows upward through resistor R_g. The effects of these currents on the voltages in resistor R_k are negligible compared with the voltages resulting from the plate current. The gain and loss of charge are equated in the following expression:

$$T_U\left[\frac{e_{2avg} + \Delta e^+ - e_{kmax}}{R_s} + \frac{e_{2avg} + \Delta e^+ - \alpha e_{kmax}}{R_g}\right]$$
$$= \frac{T_L}{R_g}\left[\alpha A(e_{2avg} - \Delta e^- + E_{co}) - (e_{2avg} - \Delta e^-)\right]. \tag{23}$$

A solution of (23) gives

$$e_{2avg} = \frac{\dfrac{\alpha}{R_g}\left[e_{kmax} + A\Delta e^+\left(\dfrac{E_{co}}{\Delta e^-} - 1\right)\right] + \dfrac{e_{kmax} - \Delta e^+}{R_s}}{\dfrac{1}{R_s} + \dfrac{1}{R_g}\left[1 + \dfrac{\Delta e^+}{\Delta e^-}(1 - \alpha A)\right]}. \tag{24}$$

As in condition 1, the tube cuts off when

$$\Delta e^- = e_{2avg} + E_{co}. \tag{25}$$

If the value of e_{2avg}, from (24), is substituted in (25), the solution for the lower limit α_{L_3} of the value of α at which cutoff occurs is

$$\alpha_{L_3} = \frac{1}{e_{kmax}}\left[(\Delta e^- - E_{co})\left(1 + \frac{\Delta e^+}{\Delta e^-}\right) - \frac{R_g}{R_s}(e_{kmax} + E_{co} - \Delta e^+ - \Delta e^-)\right]. \tag{26}$$

Condition 4. The tube is cut off during the period of lower input voltage, and grid current flows during the period of higher input voltage.

If the value α_{L_3} found from (26) is equal to or greater than the value α_{U_2} found from (21), the tube cuts off during the period T_L, and grid current flows during the period T_U. The two values of the output voltage are then zero and e_{kmax}. The equality of charge gained during the period T_U to the charge lost in the period T_L is expressed as follows:

$$T_U\left[\frac{e_{2avg} + \Delta e^+ - e_{kmax}}{R_s} + \frac{e_{2avg} + \Delta e^+ - \alpha e_{kmax}}{R_g}\right]$$
$$= -\frac{T_L}{R_g}(e_{2avg} - \Delta e^-) \tag{27}$$

whose solution is

$$e_{2avg} = \frac{e_{kmax}\left[\dfrac{1}{R_s} + \dfrac{\alpha}{R_g}\right] - \dfrac{\Delta e^+}{R_s}}{\dfrac{1}{R_s} + \dfrac{1}{R_g}\left(1 + \dfrac{\Delta e^+}{\Delta e^-}\right)}. \tag{28}$$

Conclusion

For any combination of circuit constants and applied voltage wave form, the position of α in the following tabulation determines the operating condition that applies:

Condition 1: $\alpha_{L_1} \leqq \alpha \leqq \alpha_{U_1}$
Condition 2: $\alpha \leqq \alpha_{L_1} \leqq \alpha_{U_2}$
Condition 3: $\alpha_{L_3} \leqq \alpha_{U_1} \leqq \alpha$
Condition 4: $\alpha_{U_2} \leqq \alpha \leqq \alpha_{L_3}$.

After the operating condition is determined from this tabulation, the circuit voltages may be found from the appropriate equations derived for the corresponding condition in the body of the paper. Under conditions 3 and 4, the upper value of the output voltage is always e_{kmax} as found in (14). Under conditions 2 and 4, the lower value of the output voltage is always zero.

Acknowledgment

The writer expresses his grateful appreciation to Professor Godfrey T. Coate, of the Department of Electrical Engineering, Massachusetts Institute of Technology, for his early sharing of interest in this problem, and for the helpful suggestions which he made following his kind review of the manuscript.

Ultra-High-Frequency Radiosonde Direction Finding*

LUKE CHIA-LIU YUAN†, SENIOR MEMBER, I.R.E.

Summary—A simple radio direction finder, operating at 183 megacycles, for observing the flight of meteorological balloons is described.

An Adcock antenna and a single-dipole antenna system, including a corner-type reflector as shield against ground-reflected waves, were used for measuring the azimuthal and the elevation angles of an incoming electromagnetic wave. Shielding characteristics of the corner-type reflector for various wire spacings, focal lengths, and wire lengths are given.

The direction finder has an accuracy of ½ degree in the determination of the azimuthal angles. An accuracy of ½ degree is easily obtained in the determination of the elevation angles when a stationary transmitter is used as target on top of Mt. Wilson at a distance of seven miles. Larger errors in the elevation angles were observed when the target transmitter was sent aloft on balloons.

Introduction

THERE HAS been a growing interest in and an increasing demand for the determination of wind velocities at high altitudes under any and all weather conditions for the purpose of meteorological studies. In normal practice, the wind velocities are obtained by sending up a free sounding balloon and determining its positions at regular time intervals by optical means, such as observations with a theodolite. It is obvious that there are many limitations to this optical method of determining the wind velocity. First, the weather must be clear; and second, the balloon must not be obscured by clouds. However, in cloudy or otherwise poor weather conditions, during which information on the wind velocities at high atmospheres is especially needed for weather studying, optical observations are no longer feasible.

The problem then is to find a simple method of determining, irrespective of visibility and weather conditions, the positions of a floating object in the air rising continuously to heights of several miles. It is apparent that direction finding by radio means would be a logical solution.

Maier[1] and others have devised radiometeorographs or radiosondes of extremely light weight to be sent aloft on free balloons. Such a device consists of a small radio transmitter and a meteorograph which sends out signals carrying information on the temperature, humidity, and barometric pressure during its ascent. The signals are received on the ground and are recorded automatically.

The position of an object in space can be defined either by two azimuthal angles, measured simultaneously from two fixed points which are at a known distance apart, and the height of the object, or by the height and the azimuthal and vertical angles referred to a single fixed point.

In applying the foregoing methods to the determination of the position of a radiosonde at any instant, it is necessary in the first method to employ simultaneously two azimuthal direction finders of high accuracy at a known distance apart, and to synchronize these azimuthal readings with the corresponding altitude obtained from the barometric-pressure signal transmitted from the radiosonde. This involves the maintenance and synchronization of two separate direction finders which should be separated by a considerable distance in order to get the required accuracy in the position of the radiosonde.

The second method, however, requires only one direction finder which is able to measure the vertical angle and the azimuthal angle simultaneously. The work described in this paper is based on the latter method. Use is made of a simple, easily portable direction-finding system, which is designed to overcome large errors encountered in the measurement of vertical angles due to ground-reflected waves when the antenna system described in another paper[2] is employed.

Apparatus

The transmitters employed as source of signals for the experiments are of the type used in radiosondes. They transmit a vertically polarized wave at 183 megacycles per second.

The radio direction finder is comprised of an Adcock antenna for measuring azimuthal angles and a single-dipole antenna for measuring vertical angles. The dipole is shielded with a corner-type reflector in order to have the dipole antenna free from the effects of reflected waves from the ground. When the dipole and the reflector system are placed in an electromagnetic field, and the reflector has the proper position and orientation relative to the dipole, the reflector produces a secondary-radiation field which neutralizes the effect of the original field at the dipole.

A simple sketch of the instrument is shown in Fig. 1. The four elements 1–1 and 1′–1′ form a directional antenna of the Adcock type.

Rods 5, similar to rods 1 and 1′, are similarly coaxially

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[1] O. C. Maier and L. E. Wood, "The galcit radio meteorograph," *Jour. Aero. Sci.*, vol. 4, pp. 417–422; August, 1937.

[2] Luke Chia-Liu Yuan, "Radio direction finding at 1.67-meter wavelengths," Proc. I.R.E. vol. 34, pp. 752–757; October, 1946.

supported by insulator 6. Rods 5, constituting a dipole antenna, feed the line 7. The dipole 5–5, together with the shield *g*, constitute the antenna assembly for determining the vertical angle of incidence of the incoming wave.

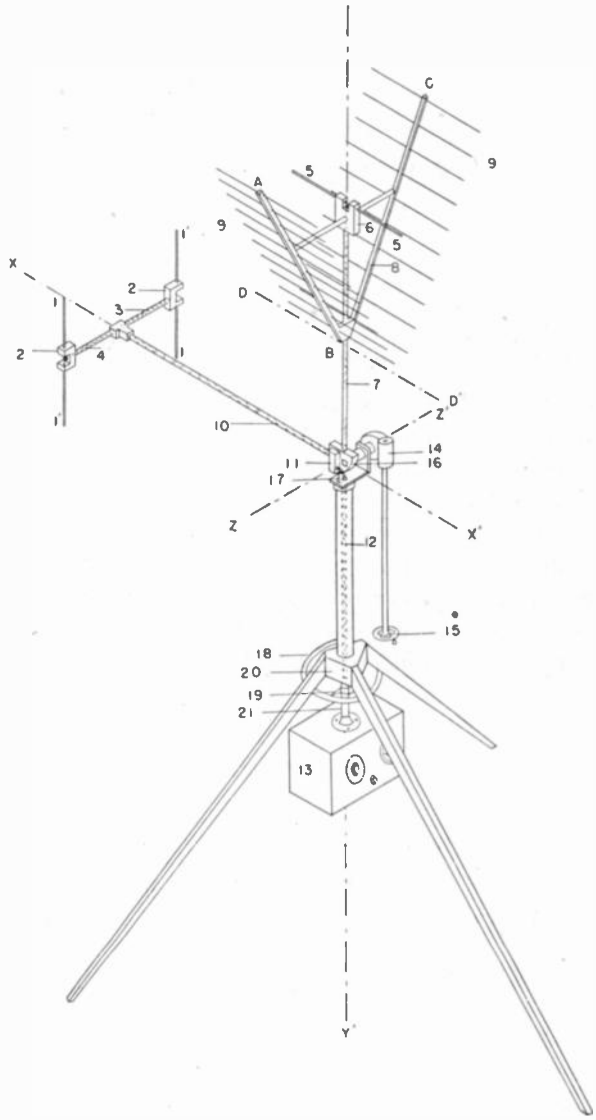

Fig. 1—Sketch of direction-finder assembly.

The shield *g*, which is of the corner-reflector type, is placed so that it shields the dipole from reflected waves from ground without impairing the receptive and directive characteristics of the dipole in the reception of the direct waves from the transmitter.

The reflector wires 9, approximately 0.6 wavelength long, are supported so as to be mutually parallel, and at the same time parallel with the dipole 5–5 in two planes whose intersection is the line D–D'. The included angle ABC between the planes is 60 degrees. The dipole 5–5 lies in a plane that bisects the angle ABC. It is parallel to the line D–D' and is placed at a focal distance p from D–D' equal to or slightly greater than half a wavelength. The spacing between the reflector wires should be at least $\lambda/60$ and preferably smaller.

The two antennas are connected through their feed lines 7 and 10 to a double-pole, double-throw switch of suitable design for the frequencies employed. By means of this switch, either antenna may be connected at will to the line 12 which feeds the receiver 13. Line 10 must connect to the electrical midpoint, which will also be the geometrical midpoint if the system is carefully constructed, of line 3. The lines 4, 7, 10, and 12 are made with two parallel No. 18 copper wires separated by victron spacers.

The two antenna systems, which are so mounted as to be rigidly held in fixed positions relative to each other, constitute the directional-antenna assembly. The axes X–X', Y–Y', and Z–Z' intersect one another at angles of 90 degrees. The dipole 5–5 is parallel to axis X–X'. Lines 7, 10, and 12 are one wavelength long.

The directional-antenna assembly may be rotated about axes Y–Y' and Z–Z'. One means of turning and controlling the rotation of the assembly about axis Z–Z' is illustrated in Fig. 1. The worm reduction gear 14 is turned by means of the handwheel 15. Rotation about axis Y–Y' may be produced directly or by some mechanical device not indicated in the drawing. The angular positions due to rotation about axes Y–Y' and Z–Z' may be indicated and measured by any suitable system.

The complete unit is shown mounted upon a tripod 20, so that the receiver 13 is one wavelength above ground. For best results, the axis Z–Z' should preferably be more than two wavelengths above ground.

The receiver 13 is of the superheterodyne type, with an output meter to indicate the signal intensity and a pair of earphones for audible indication. It must be well shielded to eliminate stray pickup. The receiver is mounted by a tubular support 21 so that it rotates as an integral unit with the antenna assembly. Advantages of this construction are that it makes better shielding possible and prevents the characteristics of the transmission lines from being altered, even though the assembly is continuously rotated in the same direction. In this way, since the relative position of the operator with respect to the two antenna systems remains unchanged during operation, any error in the measurements caused by the changing position of the operator with respect to the antenna systems is eliminated.

The procedure of operating the direction finder is rather simple. It consists of two steps in rapid succession: (1) determining the azimuthal angle, and (2) determining the elevation angle.

Results

1. *On the Shielding Properties of the Corner-Type Reflector*

Various types of reflector systems were tested to shield a dipole antenna, used to measure the elevation angles of incoming electromagnetic waves, from ground-reflected waves. These systems included a single-rod reflector, a reflector and director combination, cylindrically parabolic sheet or wire reflectors, cylindrical sheet or wire reflectors, and corner reflectors.

The corner-reflector type of shield in conjunction with a simple half-wave dipole antenna was found to be most satisfactory for the purpose. Fig. 2 is a polar diagram of the strength of the received signal, in terms of the inter-

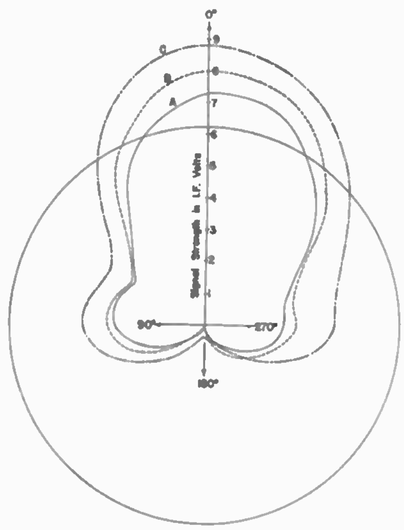

Fig. 2—Azimuthal response of $\lambda/2$ antenna with 60-degree corner reflector. (Wire spacing $\lambda/60$.) Signal voltage is expressed in terms of intermediate-frequency voltage on the plate of last intermediate-frequency stage (abbreviation: I.F. volts).

mediate-frequency voltage on the plate of the last intermediate-frequency-amplifier stage of the receiver, for various horizontal angular settings of the shield. The circle represents the uniform signal received without any shield. Maximum shielding is shown when the front end of the corner reflector is facing 180 degrees away from the incoming signal. In this setup the half-wave antenna and the reflector remained vertical, and the reflector was rotated about the antenna. The curves show the results for different focal distances p at a spacing $\lambda/60$ between reflector wires.

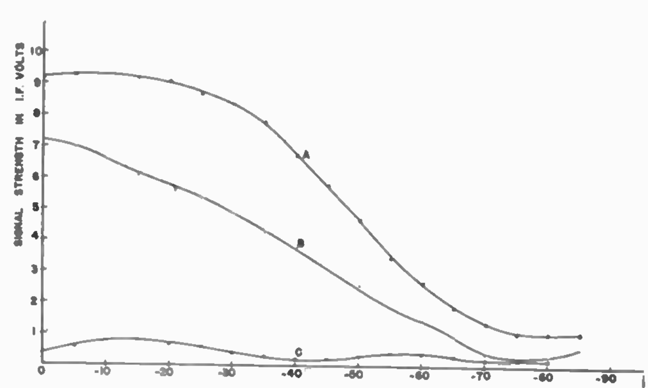

Fig. 3—Response of half-wave antenna with 60-degree corner reflector (wire spacing $\lambda/60$) in a vertical plane containing the transmitter.

It was found that a focal distance of 86 centimeters gave the best results with a good ratio of shielding to gain as the reflector swung through 180 degrees. Representative curves A, B, and C show the response for p's of 85, 86, and 100 centimeters, respectively.

Fig. 3 shows the response of the half-wave antenna in a vertical plane containing a stationary transmitter located on Mt. Wilson, about seven miles from the antenna. Curve B is the response of the antenna alone

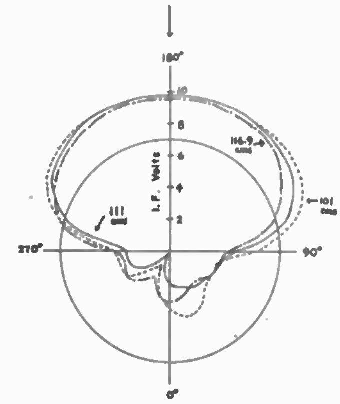

Fig. 4—Azimuthal response of $\lambda/2$ antenna with 60-degree corner reflector made of wires of different lengths. Spacing $=\lambda/7.5$.

without any shield. Curves A and C are with the shield in place facing toward the transmitter and opposite to it, respectively. These positions correspond to angles of zero and 180 degrees, respectively, in the polar diagram, Fig. 2. Curve C shows that the shielding is quite effective and fairly uniform.

In Fig. 4 are shown response curves indicating the effect on its shielding properties of the length of the wire elements of the reflector at $\lambda/7.5$ spacing. Because of

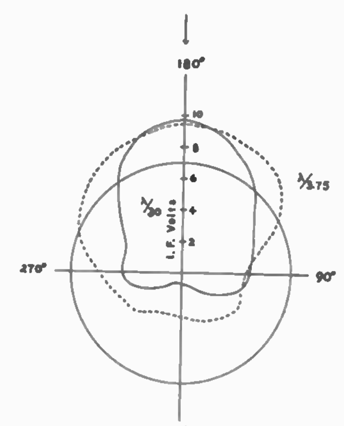

Fig. 5—Azimuthal response of $\lambda/2$ antenna with 60-degree corner reflector of various wire spacings.

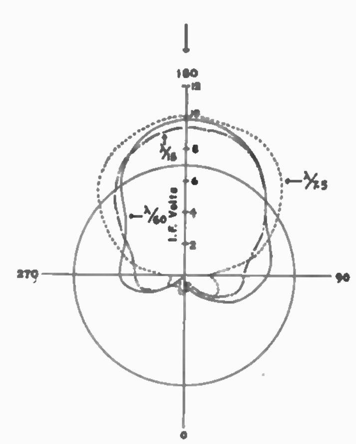

Fig. 6—Azimuthal response of $\lambda/2$ antenna with 60-degree corner reflector of various wire spacings.

the congestion of the curves near the zero-angle region, only representative curves are drawn in the figure. It is evident that the best shielding is obtained at 0.65 wavelength. This value was used as the optimum length of the wire elements in the later experiments on the wire spacings of the reflector.

Figs. 5 and 6 show the effect of wire spacing on the shielding properties of the reflector. It is seen that the closer the spacing of the wire elements, the better is the shielding, although the spacing is not too critical when it is smaller than $\lambda/7.5$. The $\lambda/60$ spacing seems to be the best in the group.

These tests were all made close to the ground. It was later found that the results thus obtained do not quite hold when the corner reflector is mounted on the instrument at a height of three wavelengths above the ground and in the vicinity of the Adcock antenna and other metal supports of the instrument. This makes it necessary to repeat the shielding experiments on reflector spacing by actually mounting it on top of the instrument.

Experiments made with an incoming radio wave emitted from a transmitter at Mt. Wilson at a vertical angle of $7\frac{3}{4}$ degrees showed that without the reflector the deviation from the true direction is over 22 degrees, while with a reflector of $\lambda/30$ spacing the deviation reduces to about one degree (see Fig. 7). From Fig. 7 it is seen that for a $\lambda/60$ spacing the null point is much

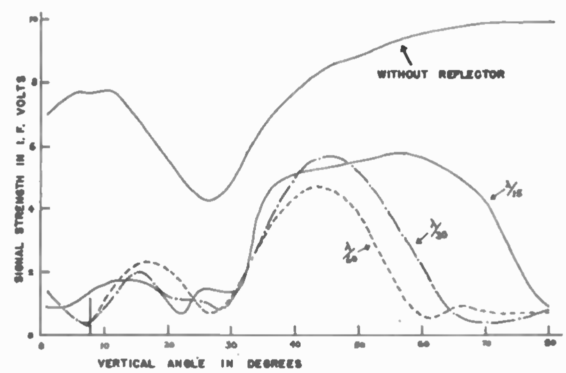

Fig. 7—Vertical response of $\lambda/2$ antenna with 60-degree corner reflector of various wire spacings. Length of wire$=0.65$ wavelength.

sharper. It is to be remembered that at this grazing angle of $7\frac{3}{4}$ degrees, the intensity of the reflected wave from the ground is extremely high. This suggests the necessity of further decreasing the spacing. The results shown in Fig. 8 for $\lambda/120$ and $\lambda/240$ spacing are quite satisfactory. In both cases the deviation is only $\frac{1}{4}$ degree, which is of the same order of magnitude as the experimental error of the instrument. It is also seen from Figs. 7 and 8 that the small humps which appear in the case of larger spacings are smoothed out in the case of $\lambda/120$ and $\lambda/240$ spacings.

Even for the $\lambda/60$ spacing there were about 120 wires which had to be fastened individually into proper place with the right spacing, and for a $\lambda/240$ spacing there were 480 wires fastened on to the reflector frame. The $\lambda/240$ spacing is already so close that further decrease of the spacing is impractical in the present method of mounting. In view of this fact, experiments were made upon the shielding properties of fine copper-wire screen. Fig. 9 shows the response curves of the reflector when various numbers of pieces of copper-wire screen are used

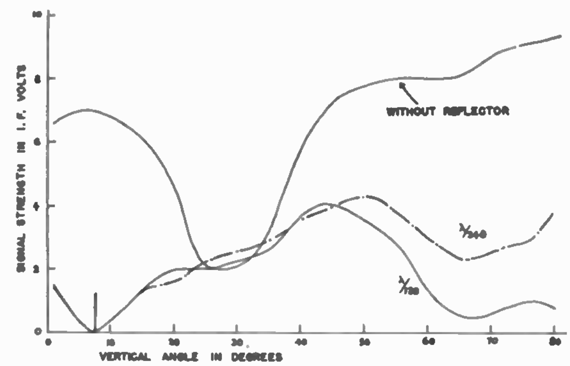

Fig. 8—Vertical response of $\lambda/2$ antenna with 60-degree corner reflector of various wire spacings. Length of wire$=0.65$ wavelength.

as the reflecting elements. Curve A shows the response when a whole sheet of the screen was used; curve B, when the screen was cut crosswise into four pieces; curve C, when it was further cut into eight pieces; curve D, when cut into twelve pieces; and curve E when it was

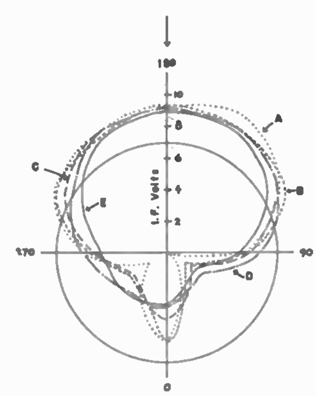

Fig. 9—Azimuthal response of $\lambda/2$ antenna with 60-degree corner reflector made of bronze window screen.

cut into sixteen pieces. It can be seen from Fig. 9 that the more the wire screen is cut, the better the shielding becomes. This obviously shows that the presence of the horizontal members of the wire screen decreases the effect of shielding.

Different sizes of wires and tubings ranging from No. 32 wire to $\frac{1}{4}$-inch tubing were tried as the reflecting elements and no appreciable difference in the efficiency of the shielding property of the reflector was observed.

2. *On the Determination of the Azimuthal and the Elevation Angles of the Direction of an Incoming Electromagnetic Wave*

The radio directional measurements were made on incoming waves emitted either from a stationary transmitter located on top of Mt. Wilson at a distance of seven miles, or from a transmitter sent aloft on meteorological balloons.

Table I shows the typical results of azimuthal measurements with the Adcock antenna made in an open field with the transmitter supported by a captive balloon.

TABLE I
AZIMUTHAL ANGLES MEASURED BY ADCOCK ANTENNA

Observations Made by Adcock Antenna in Degrees	Visual Observation in Degrees	Vertical Angle (at Time Azimuthal Observation was Made) in Degrees
88	88	34
87¾	88	32½
7	7¼	45
¼	½	45
¼	0	7½

This illustrates the independence of the azimuthal measurements from the vertical incidence of the incoming wave. The accuracy obtained in the azimuthal measurements is within ¼ degree.

Repeated measurements made on the elevation angles of the direction of the incoming wave emitted from a transmitter on top of Mt. Wilson are within a quarter of a degree from the true direction (whose true elevation angle is 7½ degrees). Observations were also made at various altitudes and elevation angles on transmitters sent aloft on captive balloons. Typical results of these observations, made at various times, are shown in Table II.

TABLE II
MEASUREMENTS OF ELEVATION ANGLES BY A DIPOLE ANTENNA WITH CORNER REFLECTOR

Elevation Angle of Incoming Wave as Determined by Dipole Antenna at Repeated Times in Degrees	Elevation Angle of Transmitter as Determined Visually in Degrees
32	32
20½	20
50	50
71	69
43	42½

Table III shows the measurements made on the elevation angles when the reflector was removed. This table demonstrates the great deviation in the readings from the true direction, caused by ground-reflected waves.

It is seen that, while some of the elevation-angle measurements obtained by using the direction-finder are very good and agree within ½ degree with the readings obtained visually, there are readings which differ quite appreciably from those obtained visually. These discrepancies are probably due to the fact that the antenna swings badly and that the plane of polarization of the incoming waves is thus changed. This change, in turn, affects the magnitude of the electromotive force induced in the receiving-antenna system, and hence causes the fluctuation in the output of the receiver. When the indicator needle swings badly, it is hard to determine the null point with great accuracy.

Another factor responsible for the deviations in the readings, which sometimes amounted to as much as a few degrees, is probably the decrease in the efficiency of the shielding system on account of the formation of

TABLE III
MEASUREMENTS OF ELEVATION ANGLES WITHOUT REFLECTOR

Elevation Angles of Incoming Wave as Determined by Dipole Antenna at Repeated Times in Degrees	Elevation Angles of Transmitter as Determined Visually in Degrees
3	8
12	16
7	14
19	14
25	31
28	17
30	29
40	32
60	30
68	34
90	76
98	72

a poorly conducting layer on the surface of the copper-wire elements due to oxidation, because they were under constant exposure to various weather conditions. Since, at ultra-high frequencies, practically all the current flowing in the wire is concentrated on the surface of the wire, it seems that any contamination of the surface would decrease the efficiency of the wire elements in their secondary radiation. This is especially important in the present case because the secondary-radiation field due to these wires serves to neutralize the effect of the ground-reflected waves at the antenna. Any deterioration in the efficiency of the shielding system would decrease the intensity of the secondary-radiation field, and thus cause the effect of the ground-reflected waves still to be markedly noticeable at the antenna.

A new corner-type reflector was made and gold-plated No. 30 copper wire was used as the wire elements, instead of the No. 30 bare copper wire originally used. Tests made with the new reflector on an incoming wave

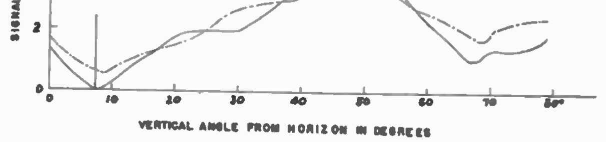

Fig. 10—Vertical response of $\lambda/2$ antenna with 60-degree corner reflector $\lambda/240$ wire spacing. Length of wire = 0.65 wavelength.
------------ without reflector
— · — · old reflector
———— gold-plated reflector

from Mt. Wilson show a marked improvement over the old reflector, the surface of whose elements had been badly oxidized. This is shown in Fig. 10, where the signal strength in intermediate-frequency output voltage is plotted against the elevation angles.

Conclusion

In summarizing the results, it is seen that an accuracy of $\frac{1}{4}$ degree is obtained in the determination of the azimuthal angles, while a less consistent accuracy in the determination of the elevation angles is obtainable. However, by comparing Tables II and III, one can immediately see the marked improvement the shield has contributed toward decreasing the effect of the ground-reflected wave in the determination of elevation angles.

The author believes that, by using proper damping devices to keep the antenna from swinging appreciably during the flight, and by further improving the reflector system, the accuracy in the determination of the elevation angles can be greatly increased.

Acknowledgment

The author wishes to thank Mr. C. E. Miller for his help in making the apparatus, and Dr. T. H. Pi for his help in the experiments.

Minimum Detectable Radar Signal and Its Dependence Upon Parameters of Radar Systems*

ANDREW V. HAEFF†, SENIOR MEMBER, I.R.E.

Summary—**This paper presents results of an early study of the influence of parameters of a pulse radar system on its sensitivity. More specifically, it describes an experimental determination of the absolute value of minimum pulse signal visually detectable through random noise with a probability of 50 per cent for a wide range of the following parameters: pulse-repetition rate r, pulse length t, intermediate-frequency bandwidth B, and video bandwidth b.**

The following empirical formula expresses the results of the investigation with considerable accuracy:

$$V_{\min} = \frac{1}{2} E_n B^{1/2}\left(1 + \frac{1}{tB}\right)\left(\frac{1670}{r}\right)^{1/6}$$

where $V_{\min}$ is the minimum detectable pulse voltage and E_n is the noise voltage per unit intermediate-frequency bandwidth of the receiver.

The application of the results to the design of search radar systems is briefly discussed.

Introduction

The magnitude of the minimum detectable signal at the receiver is one of the most important factors determining the maximum range of a radar system. The knowledge of its dependence upon the different parameters is a prerequisite for an intelligent choice of these parameters in the design of new radar systems. However, in the early days of radar development, very little information was available to the designer on the effect of such parameters as pulse-repetition rate, receiver bandwidth, pulse length, and others. Therefore, a study to determine these effects was undertaken at the Naval Research Laboratory and the following material represents a report summarizing the most significant results obtained during the early stages of the investigation which was started in the beginning of 1942. This information was presented in the form of a confidential report about three years ago and was distributed to all government and industrial organizations concerned with the design of radar systems.

The present paper is the result of the author's belief that this information is of interest to all workers engaged in the development of pulse systems and that, therefore, publication is justified.

* Decimal classification: R537. Original manuscript received by the Institute, February 13, 1946.
† Naval Research Laboratory, Washington, D. C.

Method of Investigation

Preliminary observations of the effect of some parameters were made on a complete radar system. However, for the sake of greater accuracy and ease in variation of system parameters, special laboratory apparatus was set up for more extensive study. Because characteristics of a "typical" radar receiver were of immediate interest, it was the first to be studied. As a "typical" receiver, the superheterodyne receiver with high-level second detector and one video stage was chosen. Again, type-A signal presentation was selected as being the one most commonly used at that time. Type-A presentation is one of the many methods of visually displaying radar signals on the face of a cathode-ray tube. It consists of applying the signal to the vertical deflection plate, while the horizontal deflection is made proportional to time and consequently to radar range when each sweep is initiated by the transmitter pulse.

Test signals were provided by a pulsed signal generator. In order to simulate conditions of actual radar observations, a slowly increasing signal was used. The signal was delayed by an arbitrary time interval (set by the operator) with respect to the synchronizing pulse. Thus, in order to detect the signal, the observer, not knowing the delay of the signal, had to scan the whole sweep, as in actual radar search. The magnitude of the signal at the moment when the signal amplitude was first detected was recorded. After each observation the signal amplitude was reduced to zero and the delay corresponding to the radar range was changed arbitrarily. From six to fourteen observations were made by each observer for the same set of parameters and the average value of minimum detectable signal was computed from recorded readings. Thus, this computed signal magnitude represents the signal level at which the probability of detection is 50 per cent.

Observations were made by several observers. It was found that differences between computed average values of detectable signal for observers of approximately equal experience were within the statistical error in readings of one observer. In addition, the "observer effect," when present, appeared as an approximately constant factor, which, however, for the limited number of observers employed in the initial study, was close to unity. Since no systematic study of the effect of the observers' experience had been made at that time, this fact must be borne in mind when the scope of application of results is considered.

Description of Apparatus and Technique of Measurements

A schematic block diagram of the arrangement of the apparatus is shown in Fig. 1. The receiver consisted of a conventional converter and four wide-band intermediate-frequency stages followed by an additional in-

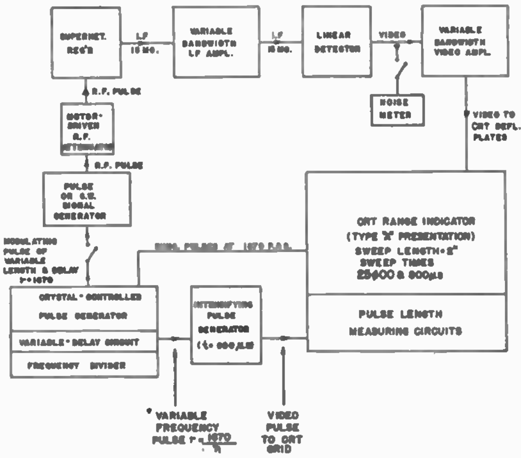

Fig. 1—Block diagram of experimental arrangement.

termediate-frequency stage of variable bandwidth, a high-level linear detector and a variable-bandwidth video filter. The pulse signals were observed on a type-A oscilloscope having a medium-persistence screen. Artificial radar echoes were fed to the receiver from a calibrated signal generator which was pulsed by means of a variable-width pulse generator. Synchronizing pulses were obtained from a master pulse generator, the repetition frequency of which was controlled by a crystal. In order to obtain the effect of lower repetition rate, a frequency divider was used and the low-frequency pulses were applied through the intensifying pulse generator to the intensifier electrode of the cathode-ray tube. This technique assured constancy of all other factors when effective repetition rate was varied.

The amplitude of the signal could be increased slowly from low to high values by means of a constant-speed motor driving the exponential attenuator of the signal generator. The starting and stopping of the motor was controlled by the observer by means of a push button. A pulse envelope of approximately rectangular shape was used. With a 1-megacycle effective bandwidth of the receiver, the difference between the pulse length at the base and the top of the pulse, as observed on the oscilloscope, was approximately 1 microsecond. The pulse length was measured directly on the scope by means of calibrating markers.

The following ranges of parameters were investigated:

(1) Pulse-repetition rate $r=1670$ to 26 pulses per second in steps of 2 to 1;

(2) Pulse length (at base) $=2.5$ to 25 microseconds, in arbitrary steps;

(3) Intermediate-frequency bandwidth $B=0.05$ to 1.0 megacycle in four steps;

(4) Video bandwidth $b=0.015$ to 2.0 megacycles in eight steps.

The characteristics of the intermediate-frequency and video filters are shown in Figs. 2 and 3. Fig. 2 shows the form of intermediate-frequency selectivity curve which was measured by means of the radio-frequency signal generator and thus includes the effect of

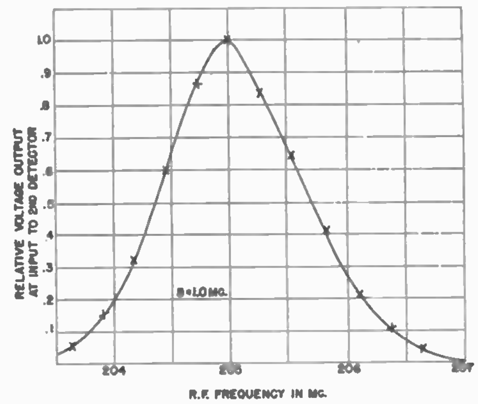

Fig. 2—Intermediate-frequency selectivity curve. (Data of October 8, 1942.)

radio-frequency circuits. The effective bandwidth B has been defined[1] as

$$B = \int \frac{G^2(f)}{G^2(f_0)}\, df$$

where $G(f)$ is the response of a linear output meter. In this work $G(f_0)$ was taken as the maximum response and the integral was obtained graphically. For the form of selectivity curve shown in Fig. 2, the effective bandwidth is somewhat greater than the bandwidth corresponding to half-power response.

Fig. 3 shows the response of the video filters, which could be easily selected by a switch on the front panel of the receiver. Video filter bandwidths indicated on this graph and later used in plotting observed data were taken as those corresponding to approximately half-power points. The shape of the video curve which shows a slight peak at a frequency equal to half the effective bandwidth was similar to video response curves of some radar receivers in use at that time.

Observations were made in the following manner. The observer, while viewing the cathode-ray tube, was allowed to tune the receiver and to adjust the setting of the gain control to a value which he considered best for detection of weak signals after a period of experimentation.

[1] D. O. North, "The absolute sensitivity of radio receivers," *RCA Rev.*, vol. 6, pp. 332–343; January, 1942.

When the observer was ready to take a reading, the operator reset the signal generator attenuator back to zero and shifted the time delay of the pulse to an

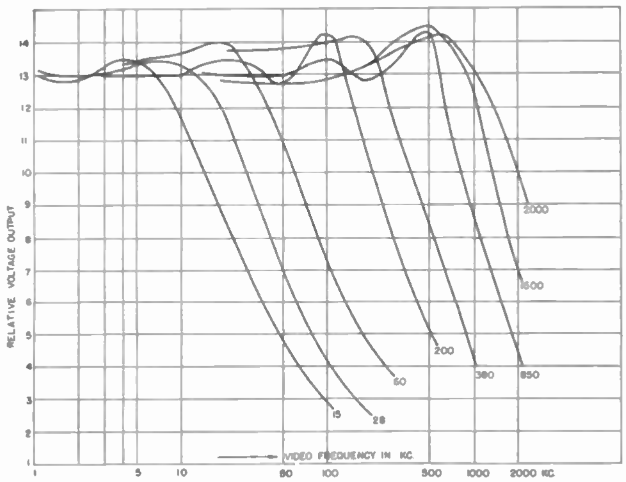

Fig. 3—Video-filter selectivity curves. (Data of August 3, 1942.)

arbitrary setting. Thus, for every reading, the observer did not know in advance the position at which the signal would appear on the scope and was obliged to scan the whole range. By pressing the push button, the observer actuated the attenuator motor and released the button immediately upon detecting the signal on the screen. The corresponding reading on the attenuator was recorded by the operator.

For each set of parameters, six to twelve observations were made and the arithmetic mean of all readings was computed and used for plotting the data. The range of individual readings for an experienced observer was of the order of two to four decibels, after suitable time was allowed for accommodation of eyes, etc. However, the same observer could repeat the run and the deviation from the average reading of the preceding run was

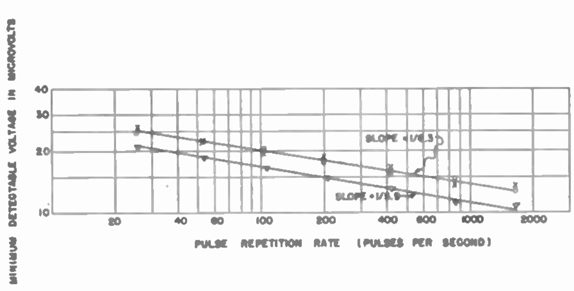

Fig. 4—Effect of pulse-repetition rate.
x = long-persistence screen (without optical filter)
o = long-persistence screen (with optical filter) (data of November 9, 1942).
∇ = short-persistence screen (data of October 16, 1942).

usually not greater than one decibel. Samples of individual runs showing the effects of variations of repetition rate, pulse length, and intermediate-frequency and video bandwidth are illustrated in Figs. 4, 5, 6, and 7.

Discussion of Results

Fig. 4 shows the effect of pulse-repetition rate. The lower curve represents an individual run, when observations were made on short-persistence screen. The upper curve was drawn through points obtained at another time, when a long-persistence screen was used with and without a yellow filter. Many curves of the same general shape have been obtained. Analyses of the results indicated that a slope of one sixth represents the best approximation, since no systematic correlation between the slope and other factors could be deduced from the available data. It may be remarked that the difference in absolute values, as indicated by the two curves of Fig. 4, is not due to the use of long-persistence screens but it attributable to other factors and should be disregarded for the present discussion.

Fig. 5 demonstrates the fact that no significant variation of detectable signal level results from variation of

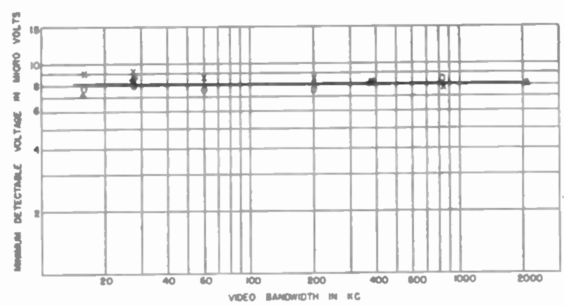

Fig. 5—Effect of video bandwidth.
Intermediate-frequency bandwidth $B = 1.0$ megacycle.
Pulse-repetition rate = 418 pulses per second.
x = 6-microsecond pulse, o = 18-microsecond pulse (Data of August 7, 1942).
• = 6-microsecond pulse, Δ = 18-microsecond pulse (Data of August 18, 1942).

video bandwidth within the investigated range. This was a rather unexpected result at the time the results were obtained, but later it was realized that this behavior is due to loss in effective signal-to-noise ratio caused by the detection process when signals are small compared to noise. In this connection it may be mentioned that for either square-law or linear high-level detectors, the behavior with respect to change in video bandwidth was found to be the same. It must be emphasized, however, that for strong signals the effect of video bandwidth variation is of the same order as for intermediate-frequency bandwidth, as far as the shape of the signal is concerned.

Fig. 6 illustrates the effect of variation in pulse length and intermediate-frequency bandwidth. In general, the longer the pulse length, the lower the level of the signal that can be detected. However, for constant bandwidth an increase of pulse length beyond a certain value does not result in a significant decrease in detectable signal level. This is clearly shown by curves marked $B = 0.27$ megacycle and $B = 1.0$ megacycle.

For ease in analysis of the results, the data of Fig. 6 have been replotted as shown in Fig. 7. Here, the ratio of detectable signal level to square root of intermediate-frequency bandwidth ($V_{min}/B^{1/2}$) is plotted against the reciprocal of the dimensionless parameter tB, the product of pulse length and bandwidth. It can be seen

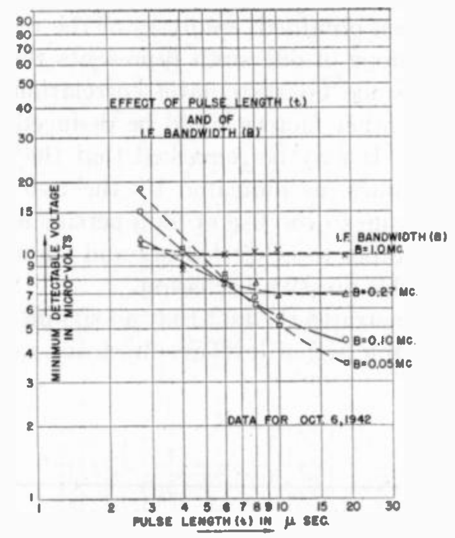

Fig. 6—Effects of pulse length and intermediate-frequency bandwidth.

that, within experimental accuracy, all points in this graph crowd around a straight line passing through the points

$$(x = -1,\ y = 0) \quad \text{and} \quad (x = +1 \text{ and } y = E_n).$$

Measurements of the intrinsic noise of the receiver E_n (noise energy per unit bandwidth) indicated that it was directly related to the minimum detectable signal. In

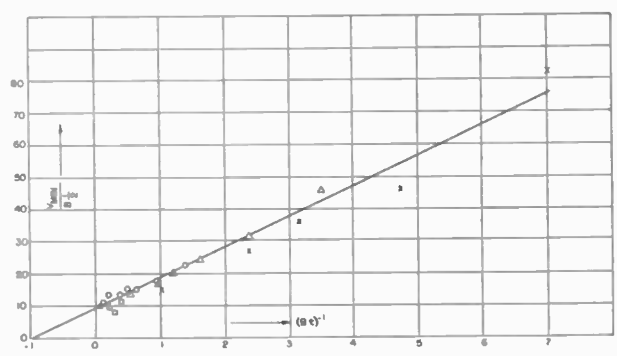

Fig. 7—Effects of pulse length (t) and of intermediate-frequency bandwidth (B) shown as a function of the parameter Bt (from data of October 6, 1942).
$x = B = 0.05$ megacycle
$\Delta = B = 0.10$ megacycle
$o = B = 0.27$ megacycle
$\square = B = 1.0$ megacycle

order to correlate the observed levels of detectable pulse signals with the absolute value of receiver noise, noise measurements were made with the same signal generator and immediately upon completion of an observational run. For this purpose, the signal generator was operated in continuous-wave condition. Since the pulsing method was such as to simply switch on and off the applied voltages, the continuous-wave level was the same as the pulse level. (The oscillator build-up time was usually small, compared to pulse length.) Thus, whenever noise measurements were made, it was possible to compare on an absolute scale the results of many observations taken at different times by different observers and under different operating conditions.

Because of large statistical errors due to limited numbers of observations, it was necessary to vary the parameters over a wide range in order to establish the law of dependence with a reasonable accuracy. From the total amount of accumulated data, it was then possible to derive an empirical relationship which describes the major results of the investigation in the following manner:

$$V_{\min} = E_n B^{1/2} \cdot \frac{1}{2} \cdot \left(1 + \frac{1}{tB}\right) \cdot \left(\frac{1670}{r}\right)^{1/6} \cdot k \qquad (1)$$

where

$V_{\min}$ = absolute value of pulse signal voltage at the receiver input terminals which can be detected with a probability of 50 per cent

E_n = the noise voltage per unit intermediate-frequency bandwidth at the input terminals of the receiver

B = the effective bandwidth of the receiver in megacycles as measured at the input to the second detector

t = the pulse length, in microseconds, of a rectangular pulse

r = pulse repetition rate in pulses per second

k = the "observer's constant" which, however, can be taken as unity for observers of average experience.

Equation (1) fits the experimental data approximately within 1 decibel over the investigated range of parameters.

The optimum value of intermediate-frequency bandwidth for detecting weak signals is

$$B = \frac{1}{t} \qquad (2)$$

which follows from (1). Therefore, when the receiver bandwidth is adjusted to an optimum for the transmitted pulse, the minimum value of detectable signal voltage is

$$(V_{\min})_{\text{opt}} = E_n B^{1/2} \left(\frac{1670}{r}\right)^{1/6} = \frac{E_n}{t^{\frac{1}{2}}} \cdot \left(\frac{1670}{r}\right)^{1/6}. \qquad (3)$$

The relationship (3) when expressed in the form

$$(V_{\min})_{\text{opt}}{}^2 \cdot t = E_n{}^2 \left(\frac{1670}{r}\right)^{1/3} \qquad (3a)$$

indicates that, for a given repetition rate and receiver noise factor, the same maximum range will be realized if the total energy contained in one pulse is the same; that is, a long pulse of low instantaneous power or a short pulse of high power will produce the same result, provided the total pulse energy is the same and the bandwidth of the receiver is adjusted for optimum in each case. The results indicate, also, how small is the effect of pulse-repetition rate and hence of the average transmitted power. For example, a change in repetition rate from 30 to 1670 pulses per second, while increasing the average power by 18 decibels, will result in an improvement of only 6 decibels in actual sensitivity of the system.

In order to illustrate how much loss in performance will result from deviation from optimum conditions, (1) can be rewritten as follows:

$$\frac{V_{\min}^2}{(V_{\min}^2)_{\text{opt}}} = \frac{1}{4} Et\left(1 + \frac{1}{Pt}\right)^2. \tag{4}$$

This relationship is plotted graphically in Fig. 8, where the change in system sensitivity is expressed in decibels. Curve A shows gain in sensitivity due to increase in

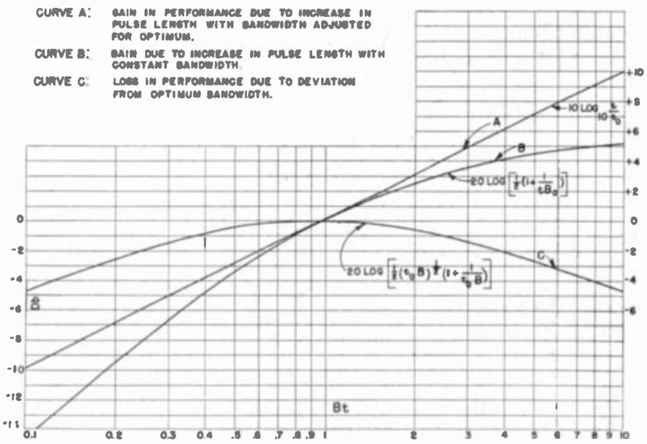

Fig. 8—Dependence of system sensitivity upon parameter *Bt*.

pulse length (with bandwidth adjusted for optimum). Curve B shows a gain due to increase in pulse length, with bandwidth held constant. Curve C shows loss in performance due to deviation from optimum bandwidth condition. The last curve shows a rather broad, flat maximum, indicating that selection of bandwidth is not critical as long as it is in the vicinity of the optimum bandwidth. For instance, the bandwidth twice as great as the optimum bandwidth results in a sensitivity loss of only ½ decibel. However, for bandwidths further away from optimum value the loss increases rapidly. When high resolution is the primary consideration in the design of a radar set, the bandwidth greater than the optimum value by a factor of 2 or 3 is usually selected, with considerable improvement in resolution and only negligible loss in sensitivity.

In design of pulse systems, it is frequently more convenient to deal with power rather than voltage. For this purpose the relationship contained in (1) can be expressed as follows:

$$\frac{V_{\min}^2}{4R_a} = W_{\min} = \frac{E_n^2}{4R_a} B\cdot\frac{1}{4}\cdot\left(1 + \frac{1}{Bt}\right)^2\cdot\left(\frac{1670}{2}\right)^{1/3} \tag{5}$$

or

$$W_{\min} = KT\cdot B\cdot(\text{NF})\cdot\frac{1}{4}\left(1 + \frac{1}{Bt}\right)^2\left(\frac{1670}{2}\right)^{1/3} \tag{5a}$$

and the expression for minimum power for optimum bandwidth of the receiver, corresponding to (3), is

$$(W_{\min})_{\text{opt}} = KT\cdot(\text{NF})\cdot\frac{1}{t}\cdot\left(\frac{1670}{r}\right)^{1/3} \tag{6}$$

where

$W_{\min}$ = minimum detectable pulse power at the terminals of the receiver
$K = 1.37\cdot 10^{-23}$ joules (Boltzmann's constant)
$T = 300$ degrees Kelvin
R_a = radiation resistance of the antenna
(NF) = noise factor of the receiver.

The application of the above formulas for the computation of maximum range of radar discloses the fact that for search radar, where detection of a target at the maximum possible range is the primary objective, it is advantageous (a) to generate pulses of the highest energy content, and (b) to use the highest pulse-repetition rate consistent with power-dissipation capabilities after condition (a) is satisfied.

In transmitters most commonly used, the peak instantaneous power is usually limited by voltage breakdown. Therefore, in order to obtain maximum range for search radar, pulses of long duration must be used. In this case, the optimum receiver bandwidth becomes quite narrow and careful consideration should be given to the effect of frequency modulation which may be incidental to pulse modulation. As the present study shows, a satisfactory compromise is to use a slightly greater than optimum bandwidth in order to accept most of the significant frequency components of the pulse even in the presence of incidental frequency modulation. The repetition rate should be chosen *after* the requirement of maximum pulse energy is satisfied. Its value is limited either by power-dissipation capabilities of the transmitter tubes or by consideration of economy, weight, or size of the equipment.

Conclusions

The results of the present investigation were found quite useful in the design of new radar systems and in the analysis of performance of existing radars. It is hoped that this information will be of value to all engineers concerned with pulse techniques.

The study of pulse systems was later extended to include many other system parameters, and a considerable amount of additional information was obtained. It is hoped that security considerations will not unduly delay disclosure of the results of these later investigations.

Acknowledgment

The author takes this opportunity to express his sincere appreciation to R. M. Page, R. C. Guthrie, A. A. Varela, I. H. Page, and to his other colleagues at the Naval Research Laboratory for their many valuable suggestions in the course of this investigation, and to J. F. Price, who constructed and operated most of the special apparatus used in this study.

Correspondence

The Institute wishes to encourage its members to present brief descriptions of their new discoveries in the realm of engineering and their novel thoughts in the domain of engineering welfare, in brief form and prior to other publication, in these columns. Correspondence on both technical and nontechnical subjects from readers of the PROCEEDINGS OF THE I.R.E. and WAVES AND ELECTRONS is invited, subject to the following conditions:

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Effect of a Differentiating Circuit on a Sloping Wave Front

The following discourse attempts to show the importance of specifying as steep a wave front as possible for trigger pulses which serve to actuate timing circuits after passage through differentiators. Consider the voltage wave front of constant slope shown by the dotted line of Fig. 1 impressed on the resistance-capacitance circuit of Fig. 2.

The expression for e_2 may be obtained by solution of the linear differential equation of the circuit in Fig. 2. This equation is

$$e_1 = iR + \frac{1}{c}\int_0^t i\,dt. \qquad (1)$$

where e_1 is the generator voltage which starts from 0 at time $t=0$ and increases in

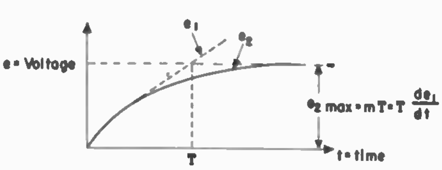

Fig. 1—Voltage wave of constant slope applied to a resistance-capacitance circuit.

time with constant slope $m = de_1/dt$ according to the equation $e = mt = t(de_1/dt)$. Substituting for e in (1), there results

$$mt = iR + \frac{1}{c}\int_0^t i\,dt. \qquad (2)$$

This equation may be readily solved in i by differentiating with respect to t:

$$m = R\frac{di}{dt} + \frac{1}{C}i.$$

The solution of the equation is

$$i = mc(1 - \epsilon^{-t/RC}), \qquad \epsilon = 2.1727.$$

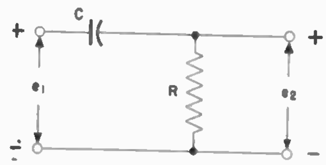

Fig. 2—Resistance-capacitance circuit.

Therefore,

$$\begin{aligned} e_2 &= iR = mcR(1 - \epsilon^{-t/RC}) \\ &= mT\,(1 - \epsilon^{t/RC}) \\ &= T\frac{de}{dt}(1 - \epsilon^{-t/RC}) \qquad (3) \end{aligned}$$

where $T = RC$, the time constant of the resistance-capacitance circuit. Study of (3) shows that for

$$t = \infty, \qquad e_2 = T\frac{de_1}{dt} \qquad (4)$$

so that this is the maximum value attained by e_2. (Call it e_2 maximum.) Therefore, no matter how large e_1 becomes, e_2 can never exceed e_2 maximum. At time $t = T = RC$, e_2 is 63 per cent of e_2 maximum, but note that at this time $e_1 = mT = T(de_1/dt = e_2$ maximum. It should also be noted that the greater the slope m or de_1/dt, the greater is e_2 maximum.

In an actual case, however, e_1 does not continue to rise indefinitely, but instead eventually levels off to a plateau. During the time of rise, which we shall call τ, conditions are as described above, but after the voltage wave has leveled off the input voltage is constant as though a battery were applied, and the usual exponential decay is obtained. The form of the output voltage e_2 is determined by the relation which the rise time τ bears to T, the time constant of the circuit. This is shown in Fig. 3.

Let us see how this theory can help in a practical example. In a Navy specification for an electronic equipment, the rise time of a trigger pulse was defined in such a manner that the pulse would require no more than 2 microseconds to rise to 5 volts. Nothing was said about a minimum rate of rise. Careful study of the implications of this definition as applied to the equipment revealed that such a pulse, after passage through a very short-time-constant differentiator, could fail to trip a particular timing circuit. It was determined that if the rate of rise between the 10 and 90 per cent points of the trigger pulse were defined as at least 5 volts per microsecond there would be no difficulty because, as can be seen from (4), e_2 maximum would be at least twice the e_2 maximum of the specification for its loosest interpretation. Therefore, it was recommended that the definition be changed to read accordingly.

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Prospective Authors

The Institute of Radio Engineers has a supply of reprints on hand of the article "Preparation and Publication of I.R.E. Papers" which appeared in the January, 1946, issue of the PROCEEDINGS OF THE I.R.E. AND WAVES AND ELECTRONS. If you wish copies, will you please send your requests to the Editorial Department, The Institute of Radio Engineers, Inc., 1 East 79th Street, New York 21, New York, and they will be sent to you with the compliments of the Institute. It would be greatly appreciated if your requests were accompanied by a stamped, self-addressed envelope.

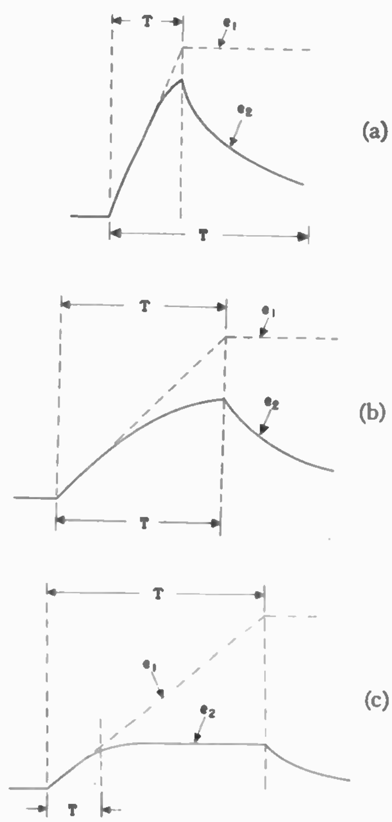

Fig. 3—Output-voltage wave as a function of the rise time of the input-voltage wave in relation to the time constant of the resistance-capacitance circuit.
(a) $\gamma < T$.
(b) $\gamma = T$.
(c) $\gamma > T$.

Locking Phenomena in Oscillators

To the Editor:

I have read with interest the paper by Robert Adler, "A study of locking phenomena in oscillators," in the June, 1946, issue of the PROCEEDINGS OF THE I.R.E. AND WAVES AND ELECTRONS. I wrote a paper[1] on a similar subject before the war, but since it was written in Polish, I think it may be of interest to your readers if I quote some of the results and method used and compare them with those of Mr. Adler.

In my paper the analysis of mutual locking of two oscillators led to an identical differential equation as in the case of one locked oscillator; it is the same as (9b) in Adler's paper. Approximate solutions of the equation were obtained by successive approximation, under the assumption that the two oscillators are detuned far beyond the synchronization range, i.e., $\Delta\omega_0 \ll B$, in Adler's notation, where B is half of the synchronization range and $\Delta\omega_0$, the detuning. The formula for the deviation $(\Delta\omega - \Delta\omega_0)$ of the beat frequency due to the synchronization effect was found to be

$$\frac{\Delta\omega - \Delta\omega_0}{\Delta\omega_0} \approx -\frac{1}{2}\left(\frac{B}{\Delta\omega_0}\right)^2;$$

this appears to be the first approximation to the exact formula (18b) obtained by Mr. Adler. Further, the beat voltage of the oscillators was examined and from the approximate solution formulas were obtained for the second- and third-harmonic content:

$$\frac{V_2}{V_1} \approx \frac{1}{2}\left(\frac{B}{\Delta\omega_0}\right); \quad \frac{V_3}{V_1} \approx \frac{1}{8}\left(\frac{B}{\Delta\omega_0}\right)^2.$$

The formulas were given in terms of the synchronization range, which perhaps is the quantity most easily measured in a beat-frequency oscillator. Experiments were made and good agreement with the formulas was obtained for detunings greater than $2B$.

Although the differential equation derived by me is the same as that derived by Mr. Adler, the methods of derivation were somewhat different: while Mr. Adler analyzed the oscillator circuit in some detail, making approximations on the way, I used what I should like to call "quasi-static" method, as follows:

When relatively slow processes are expected, and the steady-state relations between the frequency of oscillation, the magnitude, and phase of the synchronizing voltage are known, it may be assumed that they hold also in the transient state. This, assuming that the oscillator voltage remains constant, leads rapidly, without a detailed circuit analysis, to the differential equation; the extension of the analysis to the ease of two mutually locked oscillators presents no difficulty.

I hope to publish shortly a more complete account of the quasi-static method.

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Signals Research and
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[1] Z. Jelonek, "Distortion in beat frequency oscillators. Behaviour of oscillators outside the synchonisation range", *Przeglad Radjotechnicsny*, vol. 16, numbers 7-8, pp. 25-28; 1938.

DELAYS MAY OCCUR—PLEASE WAIT

It is intended that the PROCEEDINGS OF THE I.R.E. AND WAVES AND ELECTRONS shall reach its readers approximately at the middle of the month of issue. However, present-day printing and transportation conditions are exceptionally difficult. Shortages of labor and materials give rise to corresponding delays. Accordingly, we request the patience of our PROCEEDINGS readers. We suggest further that, in cases of delay in delivery, no query be sent to the Institute unless the issue is at least several weeks late. If numerous premature statements of nondelivery of the PROCEEDINGS were received, the Institute's policy of immediately acknowledging all queries or complaints would lead to severe congestion of correspondence in the office of the Institute.

Emission-Limited Diode

To the Editor:

Your contributor[1] provides a solution for the transit time (taking space charge as negligible and initial velocities zero) which is handy when the ratio of the radii of the cylinders approaches unity. For $\nu = (R_2/R_1)$ exceeding about 10 the given series converges too slowly to be convenient:

ν10	4.6	−7.1	6.5	−4.3	2.2	− .9
ν20	6	−12	14.4	−12.3	8.2	−4.5

It is, therefore, best to work with Scheibe's now well-known formula,[2] which may be written

$$t = \frac{R_2}{\sqrt{2\frac{e}{m}E}}\left[\frac{\sqrt{\log\nu}}{\nu}\cdot 2\int_0^{\sqrt{\log\nu}} e^{u^2}du\right].$$

For $\nu = 10\sqrt{\log \nu} = 1.518 \int_0^{1.518} e^{u^2}du = 4.239$.

Calling F the factor in square brackets which corresponds to the series under discussion, we have, to slide-rule accuracy,

ν	2	10	20	54.6
F	.895	1.286	1.266	1.21

As ν increases indefinitely, F tends towards the value unity. It may be mentioned that the first 5 terms of the series give F also as 0.895, 4 terms only give F 0.888, in the case $\nu = 2$.

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[1] Virgil M. Brittain, "Emission-limited diode," PROC. I.R.E., vol. 33, pp. 724–725; October, 1945.
[2] A. Scheibe, *Annalen der Physik*, 73, 54; 1924.

Correction

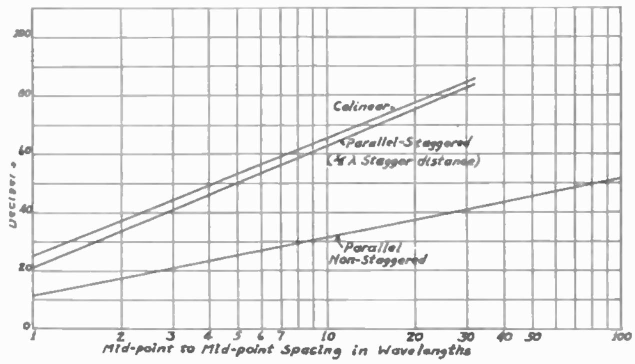
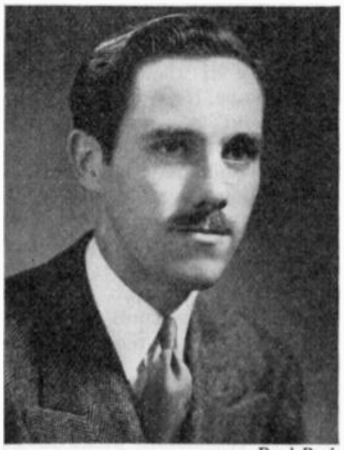


Fig. 7—Variation in decoupling with orientation of and spacing between half-wave dipoles.

Fig. 7 of the paper, "Simplifications in the Consideration of Mutual Effects Between Half-Wave Dipoles in Collinear and Parallel Orientations," by Kosmo J. Affanasiev, published in the September, 1946, issue of the PROCEEDINGS OF THE I.R.E., was unfortunately omitted. This figure appears above.

Contributors to Proceedings of the I.R.E.



Paul Boris

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Winston E. Kock (SM'45) was born on December 5, 1909, at Cincinnati, Ohio. He received the E.E. and M.S. degrees from the University of Cincinnati in 1932–1933, and the Ph.D. degree from the University of Berlin in 1934. Mr. Kock was formerly director of electronic research and development work for the Baldwin Piano Company. He is now associated with Bell Telephone Laboratories, Inc., Holmdel, N. J.

In 1938, Mr. Kock was chosen America's outstanding young electrical engineer by Eta Kappa Nu, national honorary electrical engineering society.

❖

A. B. Crawford (A'29–SM'46) was born on February 26, 1907 at Graysville, Ohio. He received the B.S. degree in 1928 from Ohio State University. Since 1928 he has been with the research department of Bell Telephone Laboratories and has been engaged chiefly in ultra-short-wave propagation studies.

A. B. CRAWFORD

❖

For a biography and photograph of Luke Chia-Liu Yuan, see the October issue of the PROCEEDINGS OF THE I.R.E.

William M. Sharpless (A'28–M '38–SM'43) was born on September 4, 1904, in Minneapolis, Minnesota. He received the B.S. degree in electrical engineering from the University of Minnesota in 1928. He has been a member of the technical staff of the Bell Telephone Laboratories since 1928, engaged in radio research work in the short-wave, ultra-short-wave, and microwave regions.

WILLIAM M. SHARPLESS

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MALCOLM S. MCILROY

❖

Malcolm S. McIlroy was born on August 28, 1902, at Rochester, New York. He received the E.E. degree in 1923 from Cornell University. He was employed by the General Electric Company as a test engineer from 1923 to 1924, and by the Brooklyn-Manhattan Transit Corporation as an equipment inspector during 1925. From 1926 until 1937, he was associated with the Central Hudson Gas and Electric Corporation, of Poughkeepsie, N. Y., as distribution engineer, district engineer, and assistant manager of the Newburgh district, and as superintendent of the Beacon district. He then transferred to the instructing staff of the department of electrical engineering at the Massachusetts Institute of Technology, where he was an instructor for three years and an assistant professor for six years while pursuing graduate studies. During the war he was an assistant director of the M.I.T. Radar School, responsible for the initial construction of the plant and for the design and installation of its power systems, and for student records. He taught principles of timing and modulator circuits to Army officer students at the Radar School. He is now engaged in thesis work leading to a doctorate in electrical engineering. He is a member of Tau Beta Pi, Eta Kappa Nu, the American Institute of Electrical Engineers, and the Society for the promotion of Engineering Education.

❖

Andrew V. Haeff (A'34–M'40–SM'43) was born in Moscow, Russia, on December 30, 1904. In 1928, he received the degree of Electrical and Mechanical Engineer from the Russian Polytechnic Institute at Harbin, China. The same year he came to the United States and majored in electrical engineering at the California Institute of Technology where he obtained the M.S. degree in 1929 and the Ph.D. degree in 1932. Until the end of 1933, Dr. Haeff was a Special Research Fellow in the Electrical Engineering Department of, the California Institute of Technology, engaging in research work on ultra-high-frequency problems. From 1934 to 1941, Dr. Haeff was a member of the vacuum-tube research section of the RCA Manufacturing Company, specializing in research on ultra-high-frequency tubes and circuits. On March 1, 1941, he joined the research staff of the Naval Research Laboratory at Washington, D. C., in order to devote his full time to naval research problems, particularly in connection with wartime development of radar.

ANDREW V. HAEFF

Dr. Haeff's present position is that of consultant for Electronics and acting chief of the vacuum-tube research section of the electronic special research division of the Naval Research Laboratory.

Books

Inductance Calculations, by Frederick W. Grover

Published (1946) by D. Van Nostrand Co., Inc., 250 Fourth Ave., New York, N. Y. 286 pages+xiv pages. 66 illustrations. 6¼×9¼ inches. Price, $5.75.

This book gives a comprehensive collection of working formulas and tables for the calculation of mutual and self-inductance. Basic principles, limitations, and methods are discussed. The formulas and dimensional units are reduced to such form as can be readily used by an engineer or physicist without reference to other books. Numerous practical examples are included in 19 of the 24 chapters.

The activities of Dr. Grover in the field of inductance calculations are well known. The book is largely an assemblage of some of his extensive work. It may be considered as a new type of book well planned to supply data for the intermediate region between calculations of highest accuracy and those using simplified or empirical formulas yielding uncertain results. Accuracies attainable are 0.1 per cent in the worst cases and much better for certain geometrical shapes such as coaxial circular filaments.

In addition to data on inductance, the book has one chapter on precision calculation of magnetic forces between coils.

In general, the formulas given are intended for very low frequencies. However, in one chapter the necessary data are included for determining changes in inductance and resistance and retaining usefulness and accuracy of the formulas as frequency is increased.

W. D. George
National Bureau of Standards
Washington 25, D. C.

Circuit Analysis by Laboratory Methods, by Carl E. Skroder and M. Stanley Helm

Published (1946) by Prentice-Hall, Inc., 70 Fifth Ave., New York 11, N. Y. 282 pages +6-page index+xvi pages. 160 illustrations. 6¼×9¼ inches. Price, $5.35.

This is a book designed as something more than just another college laboratory manual. As such it succeeds quite well in providing the student with a source of information supplementing the usual circuits texts, and at the same time overcomes the proverbial bugaboo of equipment differences between laboratories.

Written with chapters of theoretical material, much of which is presented only too briefly in the usual circuits texts, the book provides valuable background for the sets of experiments which follow each chapter. Examples of this treatment are very complete chapters devoted to the theory of instruments and their use in circuits, and to the temperature variation of resistance.

The book covers laboratory material for direct- and alternating-current circuits, the space being divided about one to two, and is apparently intended for sophomore or junior electrical engineering students. A considerable amount of space in the alternating-current circuits chapters is given to the study of series and parallel resonance, but the reviewer was disappointed to find no mention of the various network theorems, as Thevenin's, Norton's, superposition, etc. These theorems are of importance to either power or communication students, and can lead to very interesting and instructive laboratory work.

In overcoming the matter of differences of equipment in various laboratories, the authors have given experimental instructions in general terms, leaving with the student the responsibility for the exact circuits to be used and data to be taken. This should aid the student in developing his ability to analyze a problem, and help in his transition to the industrial laboratory, where detailed instructions are rarely, if ever, given.

The book as a whole is well and clearly written, but for the reviewer, the high spot was the chapter on "The Report." The chapter gives the simple rules of good practice in engineering report writing—but fails to provide a clue to where we can find more engineering students who will follow them!

J. D. Ryder
Iowa State College
Ames, Iowa

The Radio Amateur's Hand-Book, 1946 Edition, by Headquarters Staff of the American Radio Relay League

Published (1946) by The American Radio Relay League, Inc., West Hartford 7, Connecticut. 468 pages+208-page catalog +11-page index. 1249 illustrations. 6¼×9¼ inches. Price, $1.00 in continental U.S.A.; $1.50 elsewhere.

A book which has circulated 1.4 millions of copies during the past twenty years on as specialized a subject as amateur radio needs no introduction. Its scope and competence having been clearly established, a comparison of the latest edition with the one it succeeds seems most useful even though this, relatively speaking, restricts the reviewer to the realm of microtrivia.

The preparation of the 1946 edition was interrupted by VJ Day and publication was deferred to permit a major overhauling of its olive-drab-covered predecessor—a reconversion job. Consequently, there are missing from its pages such wartime features as the War Emergency Radio Service and carrier-current communication.

The introduction to wave guides and cavity resonators has been expanded and data on their dimensions and coupling methods added.

In the chapters on very-high-frequency receivers and transmitters, the wartime 112- and 224-megacycle designs have been converted or replaced by 144-, 220-, and 420-megacycle apparatus. The transmitter section, in particular, has been lengthened by about 75 per cent.

Treatment of the grounded-grid or cathode-excited amplifier neglects a highly significant feature, the ability of the driver to deliver power to the load through the electron stream of the amplifier tube. With suitable design, the driver may contribute substantially to the power in the antenna without increasing the circuit capacitances, an important consideration at the higher frequencies.

Much to be regretted is the deletion of about half the material on measurements. Among the omissions are measurements of frequency in the audible range; R, Z, C, L, and Q; receiver and transmitter characteristics; as well as designs for vacuum-tube voltmeters and various accessories for cathode-ray oscilloscopes. The previous edition will still be useful for this material.

As has been consistently true throughout the years, there have been enough important changes in this hardy perennial to justify its addition to your bookshelf even though it may rub covers with numerous of its elder brethren.

Harold P. Westman
International Telephone and
Telegraph Corporation
New York, N. Y.

Most-Often-Needed 1946 Radio Diagrams, Compiled by M. N. Beitman

Published (1946) by Supreme Publications, 9 S. Kedzie Ave., Chicago 12, Ill. 192 pages. Numerous illustrations. 8½×10¾ inches. Price, $2.00.

As indicated by the title, this booklet is an assembly of the available wiring diagrams and service information on radio-receiver models produced by approximately forty manufacturers during the early part of 1946. While the coverage is incomplete, some models are included from most of the major radio manufacturers.

The information is supplied by the manufacturers, and varies in completeness from simple diagrams, to coverage of alignment procedure, voltage readings, spare-part listings, and specific servicing information. The information on record changers is meager. The binding is permanent, and no plans are indicated for loose-leaf or other follow-up service.

In the absence of specific information from the manufacturer, this volume will assist the serviceman on the models which are covered.

H. C. Forbes
Colonial Radio Corporation
Buffalo, N. Y.

Radio Sound Effects, by Joseph Creamer and William B. Hoffman

Published (1945) by Ziff-Davis Publishing Co., 350 Fifth Avenue, New York 1, N. Y. 61 pages+x pages. 11 illustrations. 5½×8¼ inches. Price, $1.50.

The authors have written a nontechnical primer on sound effects which gives some helpful suggestions and advice intended for the beginner in radio-sound-effects technique.

Sound effects as produced for present-day broadcasting cover a great many details, both practical and technical, which would require much more material than the authors have presented.

Types of equipment and examples of each are given, also a list of some basic pieces of equipment. The importance of timing effects to cues, script marking, and studio set up are stressed. Control-room signals are described in order that the student may more easily understand the program director's coaching during rehearsal and broadcasts. The necessity of considerable practice and rehearsal are well emphasized along with the general approach to this type of work.

A chapter on recorded sound effects lists some good recordings now available and their manufacturers. "Record spotting" of a particular effect contained on a record is illustrated by pictures and description but this section could have been made clearer and more concise.

Examples of some "trick effects" and how they were created are interesting and serve the authors' contention that diligent study, experimenting, and improvising are so important.

While some constructional information is given, the book is not apparently intended by the authors as a comprehensive "how to build it or produce it" volume on sound effects but rather to give a general background to those who are contemplating work in the studio end of the broadcast field.

W. R. Pierson
71 Kensett Rd.,
Manhasset, L. I., N. Y.

I.R.E. People

Frank C. Gow

Frank C. Gow (A'44) has been appointed station director of WROL, Knoxville, Tennessee where he will have charge of all studio and transmitting personnel and operations, the installation and initiation operations of the frequency-modulation transmitter, and the installation of improved amplitude-modulation facilities.

Mr. Gow served as a ship operator for the Independent Wireless Telegraph Company from 1925 to 1927, and as an operator, announcer, and production worker for WEEI from 1927 to 1936. He then joined the Columbia Broadcasting System where he engaged in network production until 1941 when he became an operating engineer at CBS's Brentwood, New York, international short-wave stations. Mr. Gow joined the Radio Corporation of America Laboratories in 1942 where he served in both New York and Chicago.

❖

Lester N. Hatfield and Stephen Horbach

Announcement has been made by Press Wireless Manufacturing Corporation, a

SECTIONS

Chairman		Secretary
	Atlanta November 15	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 November 20	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 November 15	D. G. Haines Hytron Radio and Electronic Corp. 4000 W. North Ave. Chicago 39, Ill.
J. D. Reid Box 67 Cincinnati 31, Ohio	Cincinnati November 18	P. J. Konkle 5524 Hamilton Ave. Cincinnati 24, Ohio
H. C. Williams 2636 Milton Rd. University Heights Cleveland 21, Ohio	Cleveland November 22	A. J. Kres 16911 Valleyview Ave. Cleveland 11, Ohio
E. M. Boone Ohio State University Columbus, Ohio	Columbus December 13	C. J. Emmons 158 E. Como Ave. Columbus 2, Ohio
Dale Pollack 352 Pequot Ave. New London, Conn.	Connecticut Valley November 21	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 November 21	Joseph General 411 E. Bruce Ave. Dayton 5, Ohio
H. E. Kranz International Detrola Corp. 1501 Beard Ave. Detroit 9, Mich.	Detroit November 15	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	Max 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 10	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 December 11	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 December 4	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 November 21	W. A. Caton 132 Faraday St. Ottawa, Canada
Samuel Gubin 4417 Pine St. Philadelphia 4, Pa.	Philadelphia December 5	A. N. Curtiss RCA Victor Division Bldg. 8–9 Camden, N. J.
W. E. Shoupp 911 S. Braddock Ave. Wilkinsburg, Pa.	Pittsburgh December 9	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 November 21	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 December 3	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 December 12	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 December 9	G. P. Adair Federal Communications Commission Washington 4, D. C.
W. C. Freeman, Jr. 2018 Reed St. Williamsport 39, Pa.	Williamsport December 4	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)	
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) November 21	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

subsidiary of Press Wireless, Inc., of the promotion of Lester N. Hatfield (A'30-M'45) to the position of chief engineer, and of Stephen Horbach (A'44-M'45) to sales manager.

Mr. Hatfield began his radio and electrical training in 1924, and was for three years chief engineer of Washington State College station KWSC. For ten years he was

Lester N. Hatfield

affiliated with the Columbia Broadcasting System in New York as a technician and engineer and he served two of the war years as lieutenant in the Naval Reserve with the electronics division of the Bureau of Ships. Mr. Hatfield joined the staff of Press Wireless in 1945 where he became chief sales engineer.

Mr. Horbach served from 1941 to 1945 as chief engineer in the Operations Branch,

Stephen Horbach

Army Communications Service, Office of the Chief Signal Officer, and received a citation from Major General Frank E. Stoner (SM'45), Chief, Communications Branch of the Signal Corps, for the first twenty-four-hour communications circuits over the North Atlantic. He joined the engineering staff of Press Wireless in 1945, and is a member of the American Institute of Electrical Engineers and the Radio Society of Great Britain.

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Louis B. Bender

SUBSCRIPTION PRICES

Effective with the January, 1947, issue of the PROCEEDINGS OF THE I.R.E. AND WAVES AND ELECTRONS, the price of individual nonmember subscriptions will be $12.00 per year; subscriptions from libraries and colleges, $9.00 net; subscriptions from agencies, $9.00 net. In each case, there will be an additional charge of $1.00 per year for postage to persons and organizations not residing within the United States and Canada.

Harner Selvidge

Louis B. Bender

Colonel Louis B. Bender (M'23-SM'43) has recently relinquished his duties as supervisor of engineering production in the radio division of the Westinghouse Electric Corporation, Baltimore, Maryland, and has retired to his home in Kansas. He is a graduate of Kansas State College, Massachusetts Institute of Technology, and of the Army's Command and General Staff School, the War College, and the Industrial College. Colonel Bender also spent a year in graduate study at The Ohio State University.

He entered the communications field with the Western Electric Company in 1904 and in 1909, he joined the regular Army as a second lieutenant and was awarded the Distinguished Service Medal for his services in World War I. Prior to his retirement from the Signal Corps in 1940 to join Westinghouse, he was in administrative direction of the Corps' research and development work at its laboratories and in its Washington, D. C., headquarters for eleven years. During World War II, Colonel Bender was recalled to active military duty and served as Signal Officer, Second Service Command, at Governors Island, New York.

Meade Brunet

Announcement has been made by Radio Corporation of America's president, David Sarnoff (A'12-M'14-F'17), of the promotion of Meade Brunet (M'33-SM'43) to managing director of the RCA International Division with headquarters in New York.

Mr. Brunet graduated from Union College, Schenectady, New York. Associated with RCA since 1921, he was for five years in charge of production and distribution of RCA Radiotrons and Radiolas, and later was named manager of the Radiola Division. In 1930 he was advanced to sales manager, subsequently became general manager of the engineering products department of the RCA Victor Division, Camden, New Jersey, and was elected vice-president in charge of that department in 1945.

John M. Hollywood

John M. Hollywood

In July, 1946, John M. Hollywood (J'30-A'32-SM'45) joined the staff of Airborne Instruments Laboratory, Inc., Mineola, New York, as a consultant in the electronic engineering aspects of air navigation and traffic control systems development.

Mr. Hollywood received the B.S. degree in communications in 1931 and the M.S. degree in electrical engineering in 1932 from Massachusetts Institute of Technology. The following year, he became associated with the Electron Research Laboratories, and in 1935, he joined the Ken-Rad Tube Corporation to engage in cathode-ray-tube development.

From 1936 to 1943, Mr. Hollywood performed color-television work for the Columbia Broadcasting System, and in 1943, he went to England as a consultant on radio and radar countermeasures for the Radio Research Laboratory of Harvard University. Two years later, he returned to join the Naval Research Laboratory, continuing in similar work and serving as an electronics engineer in the development of special devices.

Recognized for his achievements in the field of color television and for his numerous articles on the subject, Mr. Hollywood holds the patent on a switching device for television color mixing.

Harner Selvidge

Harner Selvidge (A'31-M'40-SM'43) has recently been appointed director of special products development for the Bendix Aviation Corporation, where he will co-ordinate activities in the guided-missile and pilotless-aircraft fields. Two laboratories will be under his direction, at Teterboro, New Jersey, and North Hollywood, California.

Dr. Selvidge received his B.S. degree in electrical engineering from Massachusetts Institute of Technology in 1932 and his M.S. degree the following year. In 1937, he received the Sc.D. degree from Harvard University, He was an instructor in physics and communications engineering at Harvard's Cruft Laboratory and, later, served as associate professor of electrical engineering at Kansas State College. Formerly consulting engineer for Taylor Tubes, Dr. Selvidge was director of research for the American Phenolic Corporation for several years. During the war he was a member of the Applied Physics Laboratory staff of Johns Hopkins University, where he worked on the proximity fuze and, for two years, directed the group assigned to rugged vacuum tubes. He was then placed in charge of guidance and controls for guided-missile projects at the University.

A member of the American Institute of Electrical Engineers and the Society for the Promotion of Engineering Education, Dr. Selvidge was founder and first chairman of the Kansas City Section of The Institute of Radio Engineers. At present he is a member of the Papers Review Committee of the I.R.E.

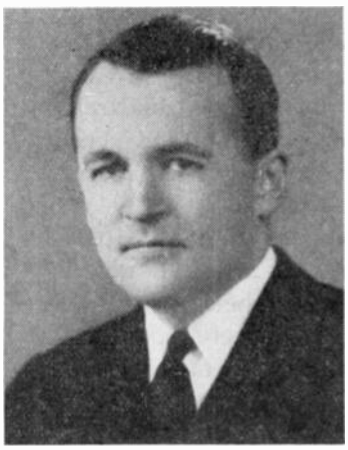
Hobart A. Ballou

Hobart A. Ballou (A'44) was one of the three engineers from the Philco Corporation, Philadelphia, Pennsylvania, at Bikini Atoll to study the effect of an atomic bomb blast on airborne electronic equipment for the Navy's Bureau of Aeronautics. Working

I.R.E. People

with the electronic co-ordinating officer, he inspected electronics apparatus in the *Saratoga's* aircraft before and after the blasts, and he was responsible for setting up and operating all television receiving and viewing systems on the laboratory ship *Avery Island*.

Mr. Ballou is a member of the Bureau of Aeronautic's airborne co-ordinating group, an organization of civilian and Navy specialists which, during the war, was represented wherever Navy aircraft were operating, and whose members know the construction and operation of every piece of Navy airborne electronics equipment.



KARL F. KELLERMAN

Karl F. Kellerman

Karl F. Kellerman (SM'46), recently released from active naval duty with the rank of commander, has been placed in charge of commercial sales and advertising by Aircraft Radio Corporation of Boonton, New Jersey.

After receiving a degree in electrical engineering from Cornell University in 1929, Mr. Kellerman joined the New York Telephone Company where he spent six years in commercial engineering and as engineer on special communications problems. In 1935, he became assistant branch office manager for the New York Life Insurance Company and was awarded the Chartered Life Underwriter designation in 1938. At the outbreak of war, Mr. Kellerman returned to technical engineering work for the Navy Bureau of Aeronautics and became head of its electronics co-ordination section. Responsible for the introduction and development of a standardized-test-equipment program; the practice of preinstallation "systems test" of over-all electronic systems for aircraft; and for much of the progress on interference reduction, he was officially commended by the Navy for outstanding performance.

Mr. Kellerman is a member of the Radio Club of America, the Cornell Society of Engineers, the Aircraft Owners and Pilots Association, Tau Beta Pi, and Eta Kappa Nu.

Rodney D. Chipp

Rodney D. Chipp (A'34–SM'43) has recently joined the general engineering department of the American Broadcasting Company, New York City, as radio facilities engineer. He will be responsible for radio-frequency and transmitter facilities for television, frequency modulation, standard broadcasting, and allied services.

Mr. Chipp received his education at George Washington University and the Massachusetts Institute of Technology. He was engaged in five-meter amateur work in 1926, and in shipboard radio operation, and operation of WKAV as chief engineer. He was employed by the National Broadcasting Company when he began his five-year period of active duty in the Navy. Assigned as radio officer for a division of transports and then transferred to the radar-design section of the Bureau of Ships, Mr. Chipp was responsible for the standardization of video and trigger levels for Navy radar repeaters and the design of shipboard video-distribution systems. Presently retained by the Bureau as a part-time consultant for the continuation of this work, he was awarded the Commendation Ribbon with a citation for his work in radar development.

The citation reads as follows: "For excellent performance of duty while serving in the Bureau of Ships in radar design from September, 1941, to October, 1945. Lieutenant Commander Chipp was personally responsible for much of the development engineering of the early radar equipments in the desperate early months of the war, and, later, for the splendid design of radar repeaters and equipment which were vital parts of combat information centers employed so successfully in the war in the Pacific. His valuable service throughout World War II was in keeping with the highest traditions of the United States Naval Service."

Mr. Chipp is a member of the Veteran Wireless Operators Association and an Associate Member of the United States Naval Institute.

George H. Timmings

George H. Timmings (A'43-SM'45) has resigned his position as sales manager of the DX Radio Products Company, Chicago, Illinois, after an association of eight years. Mr. Timmings will serve the radio industry in and around Chicago as a manufacturers' agent.

George F. Platts

George F. Platts (A'30–M'39–SM'43) has been named general manager of operations at the McQuay-Norris Manufacturing Company's electric products division. Mr. Platts, a Naval commander during the war, served as Navy officer in charge of several ordnance plants producing VT proximity fuzes.

Samuel Seely

Samuel Seely (A'39–SM'45), a member of the department of electrical engineering staff at the City College of the College of the City of New York for ten years, has recently been appointed associate professor of electronics at the Post Graduate School of the United States Naval Academy. Co-author of the textbook, "Electronics," Dr. Seely was on leave of absence at the Radiation Laboratory of the Massachusetts Institute of Technology during the past five years. He is a member of the Papers Review Committee of the Institute of Radio Engineers.

AUGUSTUS J. EAVES

Augustus J. Eaves

Augustus J. Eaves (M'33-SM'43) has been appointed director of sales for Finch Telecommunications, Inc., Passaic, New Jersey, according to a recent announcement by Captain W. G. H. Finch (J'16-A'18-M'25-SM'43), president of the company. Mr. Eaves served as a development engineer of communication systems in the Bell Telephone Laboratories, and for the past twenty years he has been general communications sales engineer for the Graybar Electric Company.

Arthur H. Lynch

Arthur H. Lynch (SM'43), former editor of *Radio Broadcast*, *Radio News*, and *Science and Inventions*, has become president of Lybig Sales Corporation located in New York City. The firm has recently been organized to secure national and export sales for radio manufacturers. Recognized as the former manufacturer of the Lynch resistor and as a pioneer of noise-reducing antenna systems, Mr. Lynch will continue to serve as New York manager of the National Company, Inc., Malden, Massachusetts, which he has represented for the past twenty years.

In their totality, the Sections of The Institute of Radio Engineers *are* the Institute. Since the successful formation and operation of a Section may present certain problems, the I.R.E. membership will be assisted by the following editorial, based on successful experience, from the Chairman of the Cedar Rapids, Iowa, Section.—*The Editor.*

New Sections of I.R.E.

Theodore A. Hunter

Since the Cedar Rapids Section of The Institute of Radio Engineers is one of the newer additions to the growing I.R.E. family, a few words about the problems involved in starting a new Section or Subsection might be in order.

The first problem to enter the mind of the group attempting to start a new Section is that of the probable number of people interested in such an organization. Section 45 of the Section Manual states: "A Section shall have a minimum of 25 Fellows, Senior Members, Members, and Associates." A listing of those already members in any area may be obtained either from Headquarters or from your governing Section Secretary. Count those already members in this area. From this number you can estimate in a rough manner the number to be counted on for membership after several years of operation. The ratio as ascertained from several other new chapters is about two and one-half to five to one.

The reason for this is quite obvious. There are a number of engineers who feel that the $10.00 fee is not a good investment when the Proceedings of the I.R.E. and Waves and Electrons may be read at the public library. Whether this is a proper view is not within the scope of this discussion, but the fact remains that a local Section does enhance this value to where the $10.00 dues are assuredly justified and will become available. Hence, the above increase in membership with the organization of local activity.

The second problem to come to the organization is that of proper membership gradation. The Cedar Rapids Section had only two people of Member grade from which to select the first Chairman. It follows that many new members were placed in the wrong grade because of the lack of the proper sponsorship. This imposes increased effort on Headquarters in making transfers later as well as inducing members to make these transfers. Some method should be worked out so that those organizing the Section do have the proper number of sponsors for the various grades involved. No solution is presented for this, but it should be recognized and dealt with in co-operation with Headquarters according to the rules and regulations.

The third problem is that of financing the start of a new Section. As it is now, a new Section fails to obtain financial aid from Headquarters for some time after it starts. A proposal was made through our Regional Meeting at Chicago that Headquarters advance one year's funds to new Sections at the time of organization. It is hoped this suggestion will be followed. If not, several methods are available. First, a "pass-the-hat" collection yields rather good returns, provided the first contributor advances a reasonably good contribution so that the rest will follow. Second, possibly some local electronics manufacturer is willing to advance, say, $100.00 to the Section in order that it be able to start functioning. There is a certain satisfaction in making a new organization financially successful in its undertaking.

The fourth problem is that of the area serving the Section. Many of the Sections serve areas which are beyond the normal sphere of influence. It seems logical that there are many communities where new Sections or Subsections may be started and present areas reclassified by Headquarters, in order for the Institute better to serve its membership and prospective membership. A letter either to the local Section Chairman or Headquarters should provide a satisfactory division of Section territory for a new Section.

In conclusion, may I, as the Chairman of one of the newer Sections, state that the present trend in membership is such that some new sections should be started by a group of "eager beavers." The social fellowship and technical information thereby obtained greatly increases the value of the I.R.E. to its membership.

Glenn H. Browning

Chairman, Boston Section

Glenn H. Browning was born in Solon, Iowa, on March 9, 1897. He was awarded with highest honors the degree of Bachelor of Arts at Cornell College, Mt. Vernon, Iowa, in 1921. He taught classes in electricity and wireless at Camp Taylor in 1918–1919 and later did graduate work at Harvard (1921–1922). He was a Research Fellow in Electrical Engineering at Harvard in 1923–1924.

In conjunction with F. H. Drake, Mr. Browning developed a tuned-radio-frequency transformer which was incorporated in a circuit later known as the Browning-Drake circuit. He became president of the Browning-Drake Corporation in 1926, and he has acted in a consultant's capacity to several radio companies. Since 1938, he has been president of Browning Laboratories, Inc. During World War II, he developed a sensitive electronic-alarm system which was widely used by the services. He is the author of numerous technical and semitechnical articles in radio magazines and periodicals.

Mr. Browning joined The Institute of Radio Engineers as an Associate in 1924, transferred to Member grade in 1928, and to Senior Member in 1943. He is a member of Phi Beta Kappa and the American Institute of Electrical Engineers.

William H. Radford

Vice-Chairman, Boston Section

William H. Radford was born on May 20, 1909, in Philadelphia, Pennsylvania. He received the degree of Bachelor of Science in electrical engineering in 1931 from Drexel Institute and in the following year was awarded the degree of Master of Science at the Massachusetts Institute of Technology. As research assistant in electrical engineering (1932–1939) he was engaged in work at Round Hill, where a program of studies of light penetration and of methods for local dissipation of fog was being carried out. After one year as assistant professor of Electrical Engineering at Massachusetts Institute of Technology, Professor Radford was promoted in 1944 to associate professor of Electrical Communications. Since 1941 he has been intimately associated with the M.I.T. Radar School, and in 1944 he became associate director of the Radar School.

Professor Radford has been a consultant on radio-communication facilities and industrial electronic-control systems since 1935 and has acted in the capacity of section member and consultant to the National Defense Research Council from 1940 to 1943.

He joined the Institute of Radio Engineers as an Associate in 1941 and transferred to Senior Member grade in 1945. He is also an Associate of the American Institute of Electrical Engineers and a member of Sigma Xi and Tau Beta Pi.

Technical Co-ordination on an International Basis in Communication and Allied Fields*

E. M. DELORAINE†, FELLOW, I.R.E

THE NEW YORK Section of The Institute of Radio Engineers has heard many valuable papers on technical subjects, but there have been only a few on a problem which is of importance, namely, the degree of international co-ordination in communication and related systems that is desirable or beneficial to all concerned.

The first question which comes to mind is whether there is a real need for any appreciable effort in this type of co-ordination; whether, in fact, the problems do not resolve themselves in the course of time without special steps being taken. In the case of communication by wire or cable, one might assume that it is sufficient to specify the transfer conditions at the junction between two systems. The other characteristics of the system might be considered of secondary importance.

In the case of radio transmission, the problem might be considered as even simpler. The characteristics of the transmission medium are fixed for all concerned and both ends must necessarily match the transmission medium. Consequently there is no real problem for interworking.

Such a superficial approach does not correspond to facts, and the past has taught us several lessons in this connection. It has been found in practice that unless agreement is reached, and at the proper time, on a large number of points, the international communication system will not function efficiently or economically. A few examples will illustrate this.

Long-distance communication by wire or cable is being handled more and more by means of carrier systems, either over pairs or coaxial cables. The individual voice bands are transposed to occupy a series of positions in the frequency spectrum. The characteristics of the voice bands and the manner in which they are transposed must be specified in great detail if two systems are to interwork.

A long-distance telephone conversation is preceded, accompanied, or followed by a series of signals; they have to do with the selection of the wanted subscriber, the selection of the toll line, the ringing of the subscriber, the metering of the call on the basis of time and distance, and in some cases with the operation of the automatic toll-ticket printer, etc. If, at the time these various signals were introduced and the methods for their transmission selected, a broad plan had been made for interconnection of large networks on an international basis, it is almost certain that the importance of using only one or very few methods would have been fully appreciated. As no such plan was made, simply because it was not appreciated then that the problem would arise, a great many systems have been introduced with resultant complications.

The problems involved in interworking become more important and more pressing as the complexity of the networks and the number of countries involved increases. The introduction of a multiplicity of uncorrelated systems can affect the system to a point where the automatic operation of a large network, involving many countries, such as the European network at present, and probably the western hemisphere network in the future, may become very difficult. One can say, at least, that the lack of broad planning at the early stages later involves an appreciable amount of additional investment in interworking equipment, and some additional operating costs.

The radio communication situation parallels, to a large extent, the wire and cable network situation. As a matter of fact, in many cases the radio operating method follows the same pattern as the methods introduced first on wires and cables, bringing, at the same time, all the complexities already indicated. The general introduction of printers on radio circuits is an example involving co-ordination especially when the service is not terminal-to-terminal, but envisages interconnecting any two subscribers on an international basis.

The general introduction of single sideband multichannel international telephone circuits involves problems which are closely parallel to those already mentioned in the case of carrier telephone systems on wire or cable.

In the not-too-distant future, the development of long-distance beamed multichannel ultra-high-frequency telephone circuits with relays will also involve a high degree of international co-ordination, if these systems are to extend over several countries.

It is not only essential in these problems to recognize the necessity of technical agreements, but it is also equally important to make plans for the probable communication networks of the world, far enough ahead, to recognize those elements which require international agreement.

Some may point out that in many cases the information available is not sufficient to allow making such plans with the required degree of accuracy. While this point must be conceded, it is also true that broad plans of this nature help substantially in visualizing future problems.

An interesting example taken from the past is that of the signals, and their methods of transmission, associated with telephone or telegraph communication, particularly in Europe. Apparently, when the various signals were chosen by the numerous parties interested for selection, ringing, metering, supervision, ticket printing, releasing, and the like, the problems were considered essentially on a regional basis. It was not realized soon enough that when all networks would have to exchange many of these signals, the lack of co-ordination at the early stages would raise problems almost impossible to solve without adding much equipment for translating signals and insuring interworking conditions.

What happened in Europe is likely to happen in the world in the future as the scale of distances rapidly decreases, particularly with the introduction of fast air travel.

Large regions of the world are without adequate communication facilities and development of these facilities on a regional basis would later reproduce on a larger scale what happened in prewar Europe, for instance. The air traffic extending over all the world will create new exchanges of goods and commodities and thereby will call for additional communication facilities, following generally the pattern of the airways themselves. In consequence, plans of the probable world communication network in the less-developed countries of the world in relation to air transport appear to be very timely.

Let us consider now, methods which are capable of dealing with the problems just described.

Conferences were called and agreements were reached on certain communication matters before World War I, especially in relation to safety of life at sea. It was not, however, until after World War I that, due to a recognition of the great expansion of communication which was going to take place, the principal international committees were created dealing first with telphony, then telgraphy, and radio.

These steps were in a large part the direct result of the presidential address of Sir Frank Gill to the Institution of Electrical Engineers in London in 1922. His proposals for international co-ordination in communication received a quick response and the Comite Consultatif International pour La Telephonie a Grande Distance (CCIF) was formed and did exceedingly good work during the period between the two wars. The pattern set by this first committee was followed to a large extent in the creation of two other committees for telegraph and radio, known respectively as Comite Consultatif International Telegraphique (CCIT) and Comite Consultatif International Radio (CCIR).

These committees are, of course, a grouping of the operating agencies. They appoint technical commissions which study the problems listed by the committee. These commissions are permanent. They include operating, manufacturing, and laboratory experts, and they issue information and recommendations on the problems submitted. The recommendations are adopted or rejected by plenary assemblies of the operating agencies. These assemblies take place at intervals of one or two years. The recommendations when adopted are issued

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as international recommendations. They are widely distributed, and it is a fact that the operating authorities almost invariably specify when procuring equipments that all materials delivered will have to meet the CCI recommendations.

The real difficulties encountered at these meetings are not generally of a technical nature, but more often are due to the fact that a group of nationals may be reluctant to give up some temporary advantage for a general benefit or subordinate any portion of the sovereign rights of their country to matters of international character. Sir Frank Gill, who since the creation of these committees has consistently been active in these matters, expresses himself in a recent letter as follows:

"I think an illustration of this difficulty of sovereignty may even lie in the sphere of economics. It is conceivable that each of several different countries might find it economical to employ somewhat different systems of communication such that the whole would not give satisfactory results when put together. They must, therefore, find a compromise in economics to get the technical solution required by means of the best *joint* economics they can devise. In other words, the engineers must in such cases cease to think of themselves as working for any particular nation, they must work for the whole group.

"I think it is along this line that the CCIF, CCIT, and probably the CCIR (though I am not so familiar with the latter) have done good work. They have faced the difficult subject of international standardization by concentrating on the essential clauses in specifications and they have not attempted to standardize rigidly any piece of apparatus. In the absence of any powers to compel nations to adopt their advice, they have worked in a very splendid manner along the lines of goodwill and although very much remains to be done, they have made very great progress in international (telephone) communication."

In spite of the shortcomings which we have stated, a large degree of order was introduced in Europe and in the world, prewar, due to the work of these organizations. The last war unfortunately partly destroyed this order through the introduction, principally by the Germans, of many non-CCI systems during the war period.

Experience was accumulated prewar on these very important matters. Consideration should now be given to the situation before us to see whether most questions requiring international agreements in our particular field are already solved, or have reached a stage where no further progress in standardization can be made, or whether there is at this stage, a possibility of great development requiring, in turn, that many steps be taken at the present time to prevent confusion in the future.

The latter appears to be the case and results from the many new aspects connected with the development of communication with mobile and air transport. This example of air navigation can be translated to an extent also in terms of telephone communication with cars, trucks, busses, or railroad cars. This latter new facility does not involve problems by far as complicated as aviation, but it does call also for a large degree of co-ordination. A person interested in telephoning from his car might be surprised to find, in ten years, that he must buy or rent a multiplicity of equipments or adaptors to maintain contacts with the telephone network even over a limited area in the United States, not to speak of the difficulties he might run into if he attempts to cross the borders.

H. M. Pease, Chairman of the Board of International Standard Electric Corporation and a veteran in international communication, says in a memorandum: "I believe that the main communication arteries in future decades will follow the air routes and that the planning engineer can play an important part in bringing about standardization of systems and apparatus used by the various operating agencies throughout the world."

It is my opinion, after some study of the problem, that the questions of ground communication along the airways, for airways operation or for public use, communication with aircraft, weather reporting, air navigation, airport traffic control, and instrument approach are all interrelated.

These methods cannot be selected on a national basis either, as airplanes already travel from country to country and will do so more and more as time goes on. In consequence, the problems must be considered on a world basis. This requires an elaboration and study of typical world plans of air traffic. These plans cannot be accurate at this stage, but they will surely help to visualize the problems to be solved.

These problems when clearly understood and listed must be studied by the appropriate technical commissions including operating, manufacturing, and research people. These technical commissions should operate very much in the same manner already found so useful in the CCI committees. They would issue their recommendations to be approved by an assembly of operating agencies and these recommendations would in all probability become the basis of future procurement by all airlines.

If this is not done, our effort will be in vain; air transport will be developed on the basis of a multiplicity of systems and methods involving as an immediate consequence a multiplicity of types of equipment, both on the ground and in the airplane. This will cause extra investment, extra load, unnecessary expenses, and a slowing down of the development in the whole field.

Imagine for a moment the complexities which will inevitably result from a lack of agreement in the assignment of radio channels or in the transmission characteristics of the numerous services already mentioned. Imagine, for instance, airports on the north Atlantic lanes, or in South America, or in Africa handling traffic of airlines of ten different nationalities, each differently equipped and utilizing different characteristics for their long-range and short-range communication for navigation, radio altimeters, distance indicators, apparatus for anticollision or the equivalent, for airport approach, instrument landing, or weather reporting. It makes a rather discouraging picture by its very complexity and one realizes that the problems involved in handling such traffic would be almost impossible to solve.

It is clear, in consequence, that plans must be developed, agreed to and followed, at least in our particular field, to permit orderly development of air transport.

International organizations already exist for making this study and preparing such plans. The most important bodies are the International Air Transport Association, working principally in terms of requirements, and the Provisional International Civil Aviation Organization, which already has issued some general international recommendations. It is possible however that the importance of the task has not been recognized except by those directly involved, and we may encounter all the difficulties set forth by Sir Frank Gill in the above quotation.

The various technical societies, such as The Institute of Radio Engineers, can help in stressing the importance of technical agreements in these fields.

The objection one can raise to forward planning and standardization is that it presumes knowing the solution to many technical problems yet to be solved. Also, that the advantages of standardization are partly balanced by its tendency to retard technical progress. There is, of course, some truth in both points. A broad plan, however, can be prepared usefully, even with the present knowledge, or in some cases an extension of this knowledge into the immediate probable future. Such plans must not be crystallized but must change as new technical information becomes available. Regarding the second objection, it is necessary to introduce a large amount of free wheeling between development and operation, permitting development to proceed while the operating standard remains unchanged for periods.

The engineers, in general, and those of this Institute in particular, have to play their part in the development of world plans in communication and allied systems to bring about the full benefits which can be derived from the technical progress resulting in large part from their own labors.

The American Standards Association—Our Colleague in Standardization*

WILLIAM H. CREW†, SENIOR MEMBER, I.R.E.

THE American Standards Association is a federation of technical societies, trade associations, and departments of the Federal Government. Its purpose is to promote engineering progress and economy in industrial production and processes through standardization of definitions, specifications, ratings, and methods of test affecting industrial equipment, manufacturing practices, consumer's goods, and the like. The Institute of Radio Engineers, as one of the sponsoring groups, has played an active role in the affairs of the Association; and now anticipates an even closer participation in matters of over-all policy and standardization in the field of radio and electronics. It is believed, therefore, that readers of the PROCEEDINGS OF THE I.R.E. AND WAVES AND ELECTRONS will be interested in a brief description of the ASA, its organization and functions, and the nature of I.R.E. collaboration in its work.

To the layman, the idea of "standardization" sometimes connotes an unpleasant form of regimentation to be resisted by an antidote which he is wont to call "rugged individualism." To the engineer, however, it is well known what part industrial standards have played in abstracting the greatest yield from human industrial effort, thereby freeing man from the shackles of needless duplication, confusion, and waste. By way of example, consider the few remaining vestiges of dual and diverse telephone services in certain communities. These remind us of what might be the situation in this country had there not been the standardization in telephone equipment and operation, accomplished through the unifying influence of the American Telephone and Telegraph Company. Were it it not for this unification, we would find business offices and homes equipped with two or more telephone sets, each covering a mutually exclusive list of subscribers. Today, standardization permits the ready interconnection of substantially all telephone systems, under whatever ownership.

The need for standardization in certain fields is well recognized by industry. But how, and by whom the standards are to be established is a matter worthy of thought. Any idea that standardization is a function to be exercised solely by a single agency dangerously contravenes the spirit of democracy. Such concentration of standardization authority in any one group would deprive that group of the advantages of the knowledge and experience of various other groups. Standards reached in such fashion would fail to win the willing support and broad adoption, on a voluntary basis, of standards arrived at by an assembly of representatives of all those having a major interest in the standards in question.

The American Standards Association is founded upon the principle that the best body to establish standards is one composed of representatives of *all* interested parties, and that the best standards are those which most nearly reflect the mature judgment of such interested parties. Usually the government is, and quite properly so, an interested party; but seldom is it the *sole* party with interests in a standard. The ASA is therefore, a federation of national associations and government departments organized to provide the machinery whereby technical societies, industries, labor, consumer, and government can collaborate in the establishment of mutually satisfactory national standards. The ASA also undertakes to further American co-operation in international standardization.

In brief, then, the function of the Association is three-fold: to provide an organization through which standards may be established, to provide stimulation of standardization work, and to provide information on standards. It is important to realize, however, that in so functioning the Association does not of itself specify standards, but rather sets up machinery and equitable democratic procedure whereby committees of interested parties may seek the consensus as to desirable standards. The ASA is the interpreter, not the administrator, of public interest.

The fields of activity of the Association cover, in general, engineering practices, safety codes, and consumer goods. In these fields its committees are concerned with such matters as dimensional standards, specifications for materials and test methods, definitions of terms, industrial safety and health codes, and standards of consumer goods sold in retail trades. During the recent war it provided an emergency procedure for handling promptly standardization requirements in the war effort.

The organization known as the ASA consists of a number of federated groups, classified as follows:

Member Bodies: Typical among these are the American Institute of Electrical Engineers, Institute of Radio Engineers, Radio Manufacturers Association, Association of American Railroads, National Safety Council, United States Department of Commerce, and the like.

Associate Members: For example, the American Home Economics Association, the American Welding Society, the National Elevator Manufacturing Industry, and so on.

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Company Members: There are some 2000 of these companies, representing all kinds of manufacture, operations, and maintenance.

Individual Members: At present, there are but a dozen of so enrolled in this class of membership.

Although the ultimate authority for operations within the Association resides in the Member Bodies, the management of affairs is carried on by the Board of Directors and the Standards Council. The Board is concerned primarily with matters of general policy, administration, and fiscal affairs, whereas the Council has jurisdiction over the machinery whereby standards are developed and is charged with the approval of standards on behalf of the Association. Both the Board and the Council draw their members from the Member Bodies

There has recently been formed an executive Committee, under the chairmanship of Howard Coonley, to assist and advise the Board, particularly in regard to meeting the enlarged scope of responsibilities to which the Association is now committed. Chief among these new responsibilities is the standardization of consumer goods in the retail market.[1]

The actual technical and investigational work in developing standards is done by specially appointed "Sectional Committees," which are responsible to the Standards Council. The correlating committees recommend projects, define their scope, and supervise the formulation of standards. It is on these levels that the standards committees of the various professional societies enter the picture, and are given full opportunity to collaborate in the establishment of industrial and commercial standards.

One of the objects of the American Standards Association is: "To provide systematic means by which organizations concerned with standardization work may co-operate in establishing American Standards. . . . " It is in this connection that The Institute of Radio Engineers has a primary interest; for among the aims set forth in the I.R.E. Constitution are: " . . . the advancement of the theory and practice of radio, and allied branches of engineering . . . , their application to human needs, ... " In line with these aims, the I.R.E. is actively concerned with standardization in all fields embraced by the theory, practice, and application of radio.

[1] Howard Coonley, "Standards and free enterprise," *Industrial Standardization*, vol. 17, pp. 71–73; April, 1946.

The I.R.E. and its members have representation in the American Standards Association at various levels. In the first place, the I.R.E. is one of the Member Bodies and as such is represented on the Standards Council by Alfred N. Goldsmith, with Raymond F. Guy as alternate. Frederick R. Lack is vice-president of the ASA and a member of its Board of Directors and of the Executive Committee. On the Electrical Standards Committee, the I.R.E. is represented by Hubert M. Turner and Harold P. Westman as alternate. The standards project in which the Institute maintains a primary interest and of which it is the sponsor is designated: "C 16; Radio." Of this, Dr. Goldsmith has been chairman and Mr. Westman secretary; and Messrs. Haraden Pratt, Goldsmith, and L. E. Whittemore represent the I.R.E. The Institute likewise has representation on numerous other projects; such, for example, as: "C 18; Dry Cells and Batteries" (H. M. Turner); "C 63; Radio and Electrical Coordination" (C. M. Jansky, Jr., J. V. L. Hogan, L. E. Whittemore); "Z 32; Graphical Symbols and Abbreviations for Use on Drawings" (Austin Bailey).

It will be of interest to members of the I.R.E. to know that the ASA maintains at 70 East 45th Street, New York City, a library containing some 25,000 standards with related books and material, for use of its members. Also, the Association has local representatives in eleven cities throughout the United States who can provide information regarding ASA activities and standards and who have files of *Industrial Standardization*, a monthly publication of the Association. The names and addresses of these local representatives may be found in the ASA Year Book or may be obtained from the ASA headquarters at 70 East 45th Street, New York 17, N. Y.

As the track goes, so go the many trains coursing over the rails and bearing myriads of passengers, each bent upon his respective mission. So it is with the many professional societies and companies which comprise the membership of the American Standards Association, each having a special purpose in its being, but guided to its destination over the well-founded and substantial roadbed of the ASA. The Institute of Radio Engineers holds in admiration the accomplishments of the Association and may well be proud of its own role, past and present, in the constructive activities of the American Standards Association.

Some Developments in Infrared Communications Components*

JOHN M. FLUKE† AND NOEL E. PORTER†

Summary—This paper describes briefly some of the recent advances made in the performance of components utilized in communications by infrared radiation. The components described include radiators consisting of infrared sources of several varieties and their associated filters. A brief description is also given of power-supply equipment for these radiators. Receivers of infrared energy including phosphors, image tubes, and photocells, with typical circuits with which they are used, are also discussed.

Introduction

THE MILITARY reasons for the application of light-wave communications are based almost solely on the need for higher security in the transmission of intelligence. Light waves offer very definite line-of-sight transmission with none of the skip, bending, or other weaknesses in security experienced in communications by radio frequencies.

The devices to be described are all used in the near-infrared portion of the light spectrum; i.e., wavelengths between 0.8 and 1.2 microns. This band has substantially the same quality of transmission as the visible-light position of the spectrum. Atmospheric conditions of poor visibility, therefore, effect increased attenuation of near-infrared energy.

Much of the effort expended on developing light-wave communications has been devoted to increasing the sensitivity of the receiving components and increasing the output of the radiators so as to extend the useful range. The purpose of this paper is to present a general description of the light-wave-communication components and their characteristics. It is further desired to emphasize that only brief descriptions will be given since it is expected that more exhaustive technical details of the components will be reported by those directly responsible for the work.

For simplicity, this paper is divided into two sections—infrared radiators and infrared receivers, one or more of each being required to effect light-wave communications.

Infrared Radiators

Output requirements of radiators can be calculated from the following relation:

$$CP = \frac{MR^2}{T^R}$$

where CP = the candle power of the radiator

M = the sensitivity of the receiver in nautical-mile candles

R = the range in nautical miles

T = the atmospheric transmission per mile expressed as a fraction (e.g., 0.6 is a normal average value of this factor).

A study of this equation reveals that increasingly larger candle powers are required for ranges equivalent to normal horizon distances. In order that radiators may be of reasonable size, it is extremely important that the sensitivity of receivers be as high as possible, in order that M be of low numerical value. This factor is the only one not fixed by conditions of a given application. Unless receivers are sufficiently sensitive, it will be found that there is little or no possibility of even hoping to obtain sufficient radiator output to effect transmission of intelligence over the most modest range. Further, in actual applications it will be found desirable to use values of T as low as 0.4 or lower, in order to provide for satisfactory reception over a reasonable range of atmospheric conditions. These conditions then fix quite definitely the requirements that radiators for a given application must meet.

For convenience the following discussion of radiators is divided into two sections—sources, which generally emit energy over a wide band of the spectrum including the visible portion; and filters, which render the emitted energy invisible to the unaided eye. In addition, power supplies for certain types of radiators will be described briefly.

Infrared Sources

The simplest source of light-wave energy is the familiar electric lamp. This type of source has been widely used with coded intelligence transmitted by keying the lamp circuit. The spectral emission of a typical lamp is given in Fig. 1. Since it is desired to

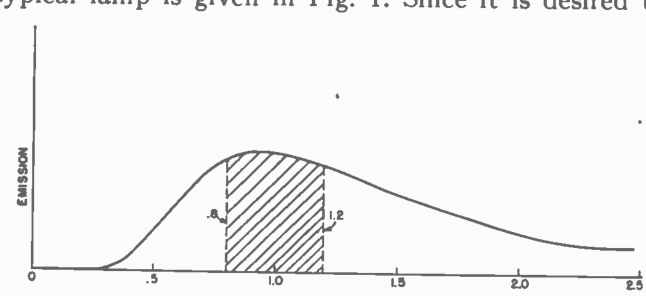

Fig. 1—Spectral energy distribution of tungsten filament at 3000 degrees Kelvin.

blank out all the energy below 0.8 micron, and further, since most receiving elements with which this type of source is generally used are not sensitive to energy above 1.2 microns, the over-all efficiency of such a source for the intended purpose is not very high.

The principal disadvantage to this type of source,

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† Bureau of Ships, Navy Department, Washington, D. C.

however, is not efficiency, but its inherent slow speed of response. The incandescent and nigrescent time curves for a typical lamp are given in Fig. 2. The relatively

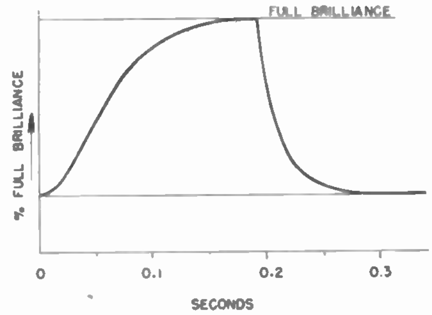

Fig. 2—Incandescent and nigrescent time curves for tungsten lamp.

long time required to reach full brilliancy and to extinguish limits Morse code speeds to about 8 words per minute. A scheme developed to reduce incandescent time is shown in Fig. 3. The circuit provides a high-

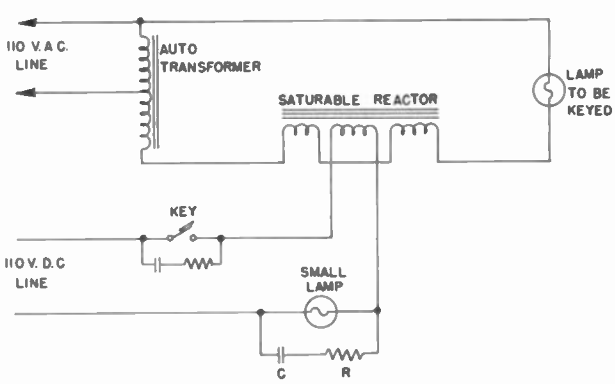

Fig. 3—Saturable-reactor circuit to reduce lamp incandescent time.

voltage start which effectively reduces incandescent time. However, in most communication systems employing the simple lamp source, characteristics of the receivers themselves also limit code speed so that about 12 words per minute is the maximum that can be obtained in the simpler types of systems.

A mechanical method for increasing code speeds with lamp types of sources has been considered, this development evolving around a high-speed shutter. A comparison of shutter speed with incandescent and nigrescent time can be observed by comparing Figs. 2 and 4. While this is considered a well-designed shutter from a

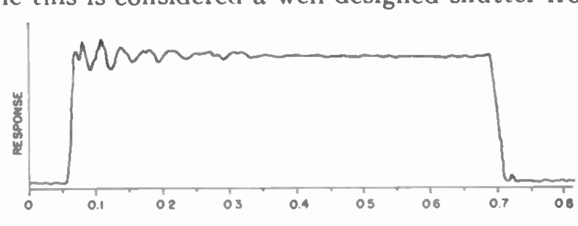

Fig. 4—Characteristics of high-speed shutter.

speed standpoint, the requirements of ruggedness, resistance to shock, vibration, and weathering, and continuous operation under adverse conditions present complex design problems not yet fully solved.

Usually the type of radiator employing incandescent lamps is used with the converter tube in an image-forming type of receiver. The radiator is keyed in Morse code and the receiver "sees" the code by visual presentation in which the converter tube receives infrared energy and performs electronically its conversion to visible light. A further description of this tube is given later. Many configurations of the lamp-type radiator

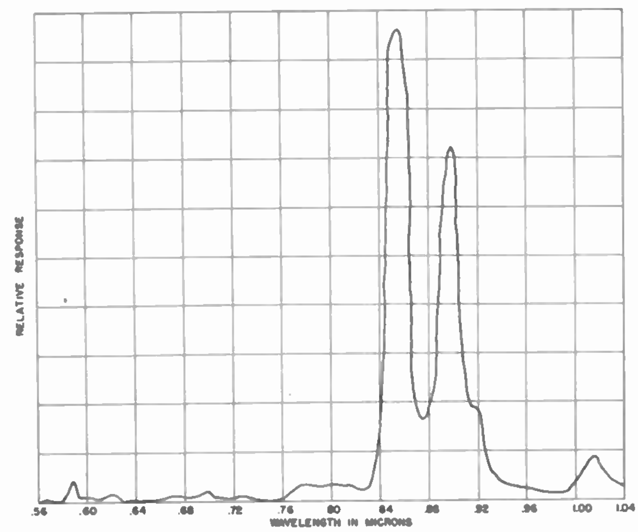

Fig. 5—Spectral response of caesium-vapor lamp.

have been used in service. Sources giving all-round coverage may consist of a lamp, a filter, and a Fresnel lens. Directional radiators either employ separate reflectors or the sealed-beam lamp construction. It is believed of interest at this point to add that the rigid high shock and vibration requirements of naval-equipment specifications have led to much development and improvement in rugged and shockproof lamps.

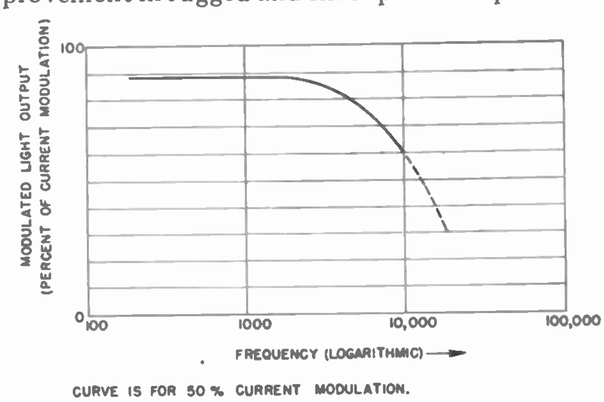

Fig. 6—Modulation characteristics of the caesium lamp.

In receivers employing photocells, effective operation requires that the light source be modulated so that alternating-current amplifiers can be used with the photocells. The lamp source above can be chopper-modulated by a rotating slotted cylinder to produce satisfactory results, but the limitations in code speed remain, of course, since keying of the lamp filament is still required. Further reduction of lamp response time can be effected by decreasing the mass of the filament. Such a source has been developed employing a lamp very similar to the commercial type S6, 6-watt pilot lamp. Because of the very fine filament in a 220-volt lamp of this type and its consequent low thermal mass, it will furnish a modulated light output on the order of 30 per cent when directly excited by low-frequency alternating currents. The use of half-wave rectification or special wave shapes provides a further increase in the modulated-light output. To obtain sufficient intensity from such a small unit source, practical applications use many lamps in parallel with a trough-type reflector. Code speeds up to the limit of most receiver capabilities are readily obtained.

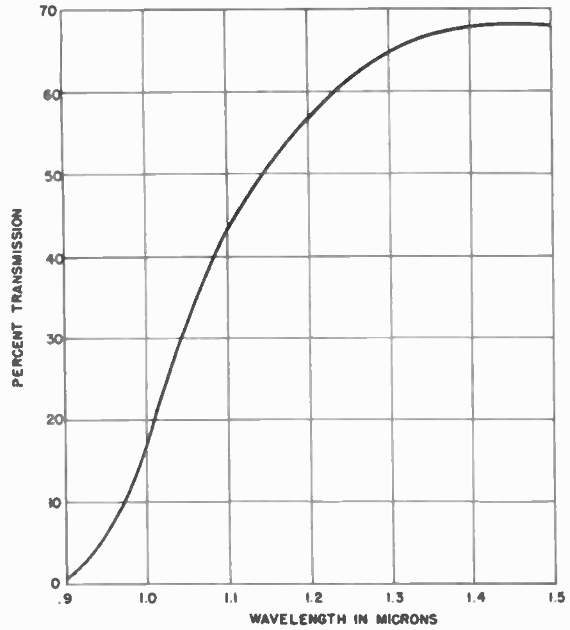

Fig. 7—Spectral transmission of glass filter.

The ideal answer to the source problem would be a selective radiator that could be tuned to emit energy only over a narrow band in the desired portion of the spectrum. For the near-infrared portion of the spectrum the best practical realization of this goal has been effected through the development of the caesium-vapor lamp. Caesium emits radiations in two principal bands just beyond the visible, 0.8521 and 0.8944 micron respectively. The construction of this lamp is similar to that of the sodium-vapor lamp in that it utilizes an inner bulb in a vacuum flask. A spectral response curve of a typical caesium lamp is shown in Fig. 5. The lamp is readily modulated up to 90 per cent with low distortion out to the higher audio frequencies, as illustrated in Fig. 6. Light modulation is approximately 90 per cent of current modulation. This source provides the desired flux with a fairly wide optical field of view, thus making it useful as a radiator in a voice-modulated communication system. The efficiency of this radiator is comparatively high, since its output in the infrared is about five times that of the tungsten source for the same input power. For similar reasons, the operating-temperature requirements and denseness of filters for this source are much less than those for the incandescent-lamp radiator, which further provides greater infrared output per watt. Modulating and attendant control circuits for this lamp are briefly described later.

The concentrated-arc lamp, flash lamps, and gas-discharge tubes have been the subjects of continued effort and research to provide improved sources for all types of light-wave-communication systems. Still other effort has involved methods of accomplishing both mechanical and electrical modulation, stabilization, scanning, automatic call-up, automatic alignment, and other techniques similar to those employed in radio apparatus.

Infrared Filters

The first requirement for a suitable filter for these applications is visual security or cutoff of the visible energy. This factor is determined to a great extent by the application for which the equipment is designed, but generally a high degree of visual security is essential. Fundamental design parameters include response characteristics of the source, the human eye, and the receiving element. The problem of obtaining efficiency is not simplified by the relatively narrow band between the peak in response for many receiving elements and the eye's response near the infrared. Some well-known infrared filters such as Wratten 87 have many desirable characteristics with relatively high efficiency, but lack durability and are unusable for most naval applications of infrared radiators. It is important that filters possess the ability to withstand the many severe operating requirements, such as high impact shock, gun-blast pressures, high temperature, and weathering, always necessary to naval equipment.

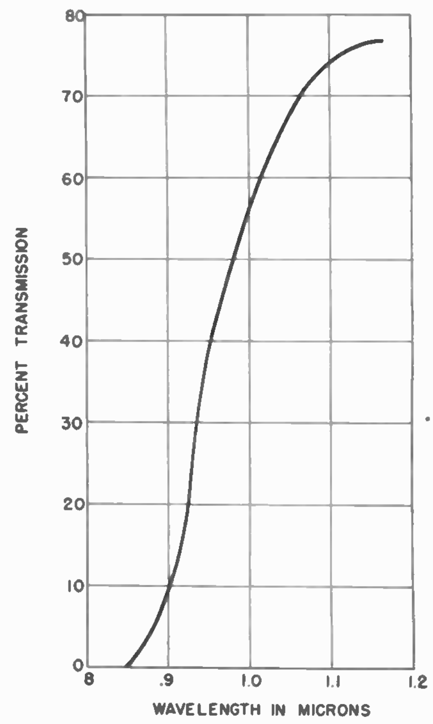

Fig. 8—Spectral-transmission characteristics of plastic filter.

Glass has been found satisfactory in the development of a rugged, high-operating-temperature filter for use with the incandescent-lamp source. The spectral transmission characteristics of such a filter are shown in Fig. 7. The lower operating temperature and more infrared-energy-selective sources, such as those employing the S-6 lamps and caesium lamp, allow the use of more efficient filters of plastic materials. The attenuation characteristics of a plastic type of filter developed for this purpose are given by Fig. 8. It will be observed that this filter passes an appreciably greater percentage of the energy longer in wavelength than 0.8 microns than the glass filter for the same visual security. However, it will not withstand as high an operating temperature.

The development of filters for naval infrared equipment is a problem of much complexity in that the rigid physical operating requirements limit the incorporation of otherwise desirable response characteristics.

Radiator Power Supplies

The circuit of Fig. 9 is a simplified schematic of the power supply used with the radiator utilizing the S-6 lamps described heretofore. This system delivers a pulsed wave by electronic means from a 3-phase power source. An approximation of the output wave is shown in Fig. 10. As is conventional in polyphase rectifiers, the transformers feeding the main thyratrons are provided with double secondaries connected to balance out direct-current components. The three smaller thyratrons (type 2050) form the trigger-pulse generator and supply pulses at three times the supply frequency to the trigger tube. By adjustment of the circuit constants, the main rectifier tubes can be caused to fire at integral and fractional multiples of the supply frequency to provide various frequencies and wave shapes of output pulses. As a matter of interest, waves at various points in the circuit are shown in Fig. 10. The small rectifier supplies direct voltage for operating the trigger tube. Actual equipment utilizing this principle includes a number of refinements to control and limit output power, to simplify calibration of the output, to suppress interference, and to provide over-all stability.

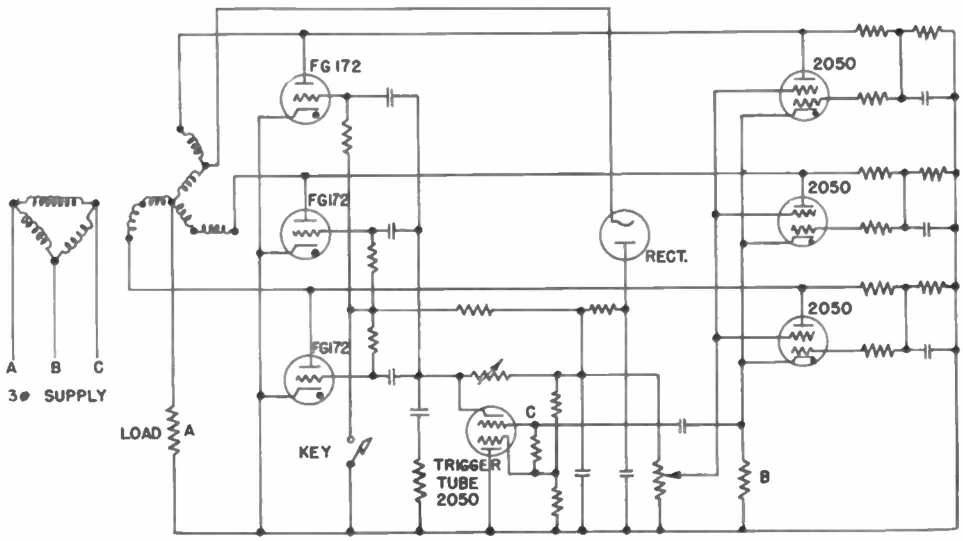

Fig. 9—Schematic circuit for power supply for S-6 lamp radiator.

The basic circuits involved in the starting, operation, and modulation of the caesium lamp are considered of interest. This lamp, like the familiar sodium-vapor lamp, must be started after a warm-up period and it must be supplied with a high-voltage discharge to initiate ionization of the caesium vapor. After starting, the arc is maintained and stabilized by a direct-current bias. This is usually accomplished by applying direct current to the lamp through a ballast resistor. A satisfactory method of modulating the arc is accomplished through the application of modulating voltage directly across the arc. Since the impedance of the arc is very low, in the order of a few ohms, this is effected through

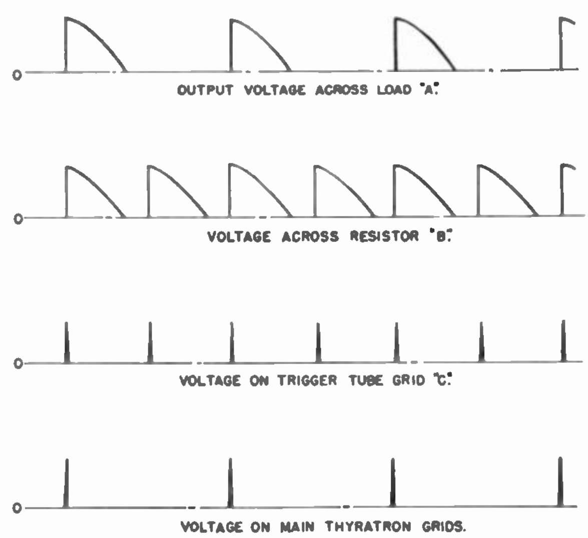

Fig. 10—Typical wave forms in special power supply of Fig. 9.

the modulator output transformer and a large series capacitor. Since damage may result to the lamp if it is started too quickly, a fairly long time delay on starting is imposed. Accordingly, during stand-by, the lamp is operated at a reduced direct-current bias. When the lamp is being utilized for voice communication, the low frequencies are purposely attenuated to prevent extinguishing the arc at high modulation levels. The various basic circuit requirements for the above operations are shown in the simplified schematic of Fig. 11. Closing switch *1* energizes the circuit. After the required delay for lamp warm-up, switch *2* is closed, which applies high voltage for starting the arc. When the arc is established, switch *3* is closed, applying the direct voltage, and at the same time switch *2* is opened to remove the starting transformer from the circuit. Switch *4* may now be closed to effect modulation. Switch *5* is for stand-by operation and increases the ballast for stand-by to effect operation at reduced voltage and maintain ionization of the tube.

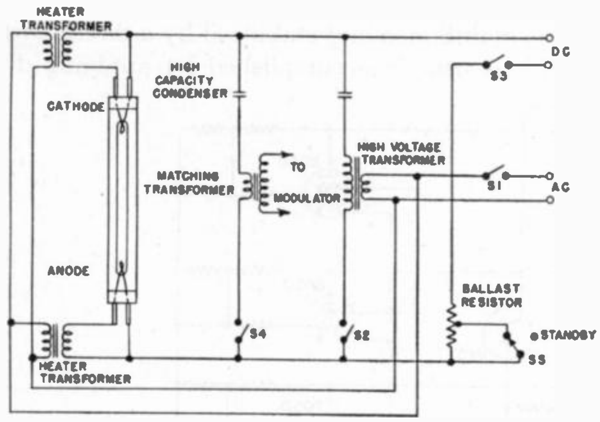

Fig. 11—Starting and modulating simplified circuit for caesium lamp.

Infrared Receivers

Image-Forming Receivers

Image-forming infrared receivers or viewing tubes are principally of two types, the electron image tube and the phosphor-button receiver. The function of these types of receivers is essentially to convert infrared energy to visible light and, through an appropriate optical system, provide a picture presentation to the observer. The simpler of these is the phosphor-button type in which the energy conversion is accomplished by phosphorescent materials composed of inorganic earth salts which exhibit the property of afterglow or phosphorescence when excited by light energy or by alpha particles from radioactive materials. After sufficient excitation, these phosphors continue to glow for several hours with a gradually diminishing brightness. Infrared radiations falling on the surface stimulate the phosphor and thereby increase the brightness. Removal of the infrared radiation returns the phosphor to substantially its normal state of afterglow for the intensities and durations of infrared radiation normally encountered in signaling. A phosphor having a suitable time constant of response and degeneration makes possible the receiving of a coded signal of infrared energy. Charging the phosphor before use can be accomplished in a number of ways depending upon the type of phosphor used, such as subjecting the button to the light from a small lamp, exposure to daylight, or activation by the close proximity of a radioactive material. All three of these methods have been used. A simple sketch of a phosphor-button type of receiver is shown in Fig. 12. Much effort

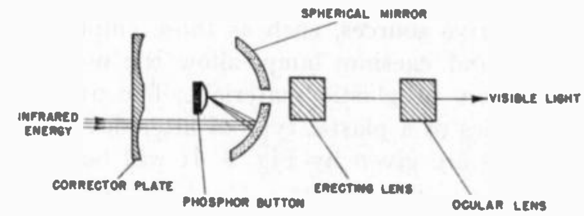

Fig. 12—Phosphor-button-type receiver.

and research have been expended in the development of this type of instrument. Improvements in the order of 1000 to 1 over first equipments have been realized.

The phosphor-button type of receiver is well adapted for coded infrared communication because of its relatively short degeneration time, its simplicity, and small size. However, where better resolution for viewing or higher sensitivity is required, the electron image tube is more satisfactory. A sketch of a typical electron image tube is shown in Fig. 13. The tube consists of an

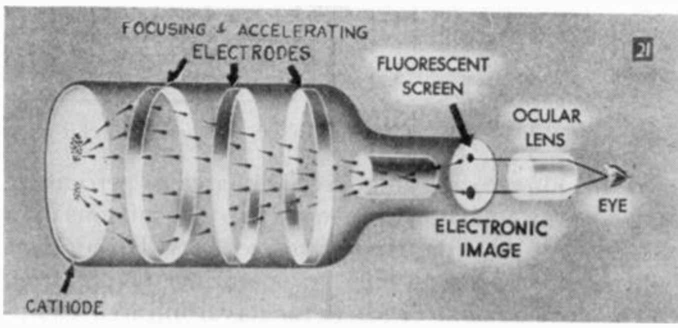

Fig. 13—Schematic arrangement of 1P25 electron image tube.

evacuated glass envelope, a face plate whose inner surface is coated with a caesium-and-silver compound to form a cathode, accelerating and focusing anodes, a Willemite screen, and a hemispherical lens. The cathode is sensitive to radiations from 0.3 to 1.2 microns with a broad peak at 0.8 micron The screen emission peaks at 0.525 micron, which is well suited to a dark-adapted eye.

A schematic electrical circuit of the image tube is shown in Fig. 14. A potential of approximately 4000

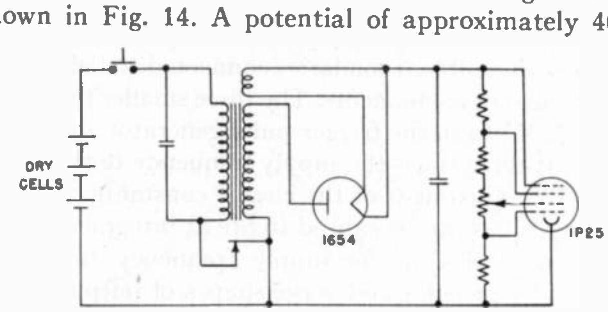

Fig. 14—Schematic circuit of the electron-image-tube and portable power supply.

volts is applied across the tube, with various values applied to the anodes through a voltage-dividing resistor. Electrical focusing is achieved by adjustment of a potentiometer. The instrument is provided with a small, light-weight power supply fed from dry cells. Actual weight of the power supply, including the batteries, vibrator transformer, rectifier, and filter, is less than 2 pounds.

Both conventional and Schmidt-type optics have been employed in production equipments, using both glass and plastics as lens materials. The phosphor-button-type receiver requires an erecting and ocular lens in the eye piece. Erection is accomplished within the 1P25 tube so that, for the electron image receiver, an ocular alone suffices.

Photocell Receivers

While the image-forming type of receiver is well adapted to a simple manually operated communication system, systems operating from a central control panel similar to radio methods require a suitable receiving head with auxiliary equipment, such as scanning and stabilizing devices. The heart of this receiver head is a highly sensitive thallous-sulfide photocell whose successful development on a production basis has been one of the principal contributing factors in performance to justify the practical application of this type of equipment. The sensitivity of this cell is far greater than that of formerly available commercial photocells, and the response is peaked in the infrared as shown in Fig. 15. This cell, known as the TF cell, is a photoconductive type of high internal impedance (up to several megohms and varying with ambient temperature). For its operation a polarizing voltage is required. Limits of sensitivity are established by the noise generated in the cell itself. Application of the cell in obtaining maximum sensitivity involves the minimizing of noise generated in the tubes and components of first amplifier stages. Frequency response of the cell is shown in Fig. 16. While the response appears to be far better at the low-frequency end, the over-all sensitivity of circuits employing the cell remains somewhat constant over a reasonable range because of noise considerations, provided a constant bandwidth is maintained.

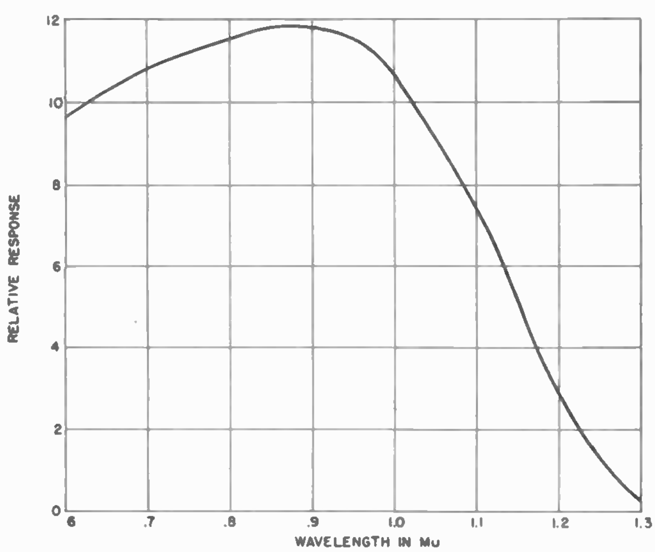

Fig. 15—Spectral response of typical thallous-sulfide cell.

One disadvantage to the TF cell is its lack of sensitivity for daylight use. Better day-and-night operating characteristics and faster response are provided in cells of the photomultiplier, wide-area-cathode photoemissive, and other photoconductive types. Much effort is being expended in the direction of obtaining higher sensitivity, higher frequency response, improved stability characteristics, and increased ruggedness.

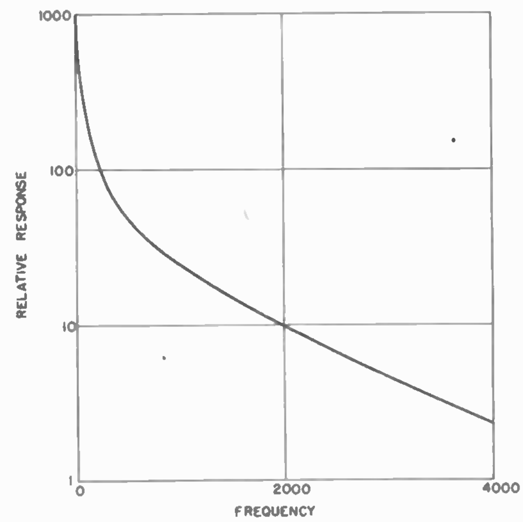

Fig. 16—Frequency response of TF cell.

Photocell Amplifier Circuits

The many complicated problems in the design of infrared communication equipment for naval use include such items as the desired range under various conditions of atmospheric transmission, limits of size and weight for receiving heads and radiators to be mounted topside, operation under conditions of shock and vibration, and limits in allowable optical field of view as determined by such factors as stabilization for roll and pitch, rate of scan, alignment methods, and other pertinent factors. These problems generally make it necessary to design for maximum available sensitivity in the photocell receiver, and accordingly the associated amplifier circuits have been the subject of much attention. As was stated before, sensitivity in the high-impedance TF cell is limited by noise, which is in the order of a few microvolts, so that for maximum sensitivity noise generated in the tubes and components of the first stage must be held to a minimum. High-impedance inputs at very low noise level dictate that preamplifiers be located directly with the cell. In one case, the first tube is mounted back to back with the cell socket.

The TF-cell amplifier circuit for equipment designed to receive low-frequency-modulated light is shown in Fig. 17. In this circuit, direct current is used for the heaters of all stages. The polarizing voltage is applied to the cell through a low-noise-level load resistor of about 5 megohms. This circuit has a noise level referred to the grid of the first stage of between $\frac{1}{2}$ and 3 microvolts, which is capable of being maintained under

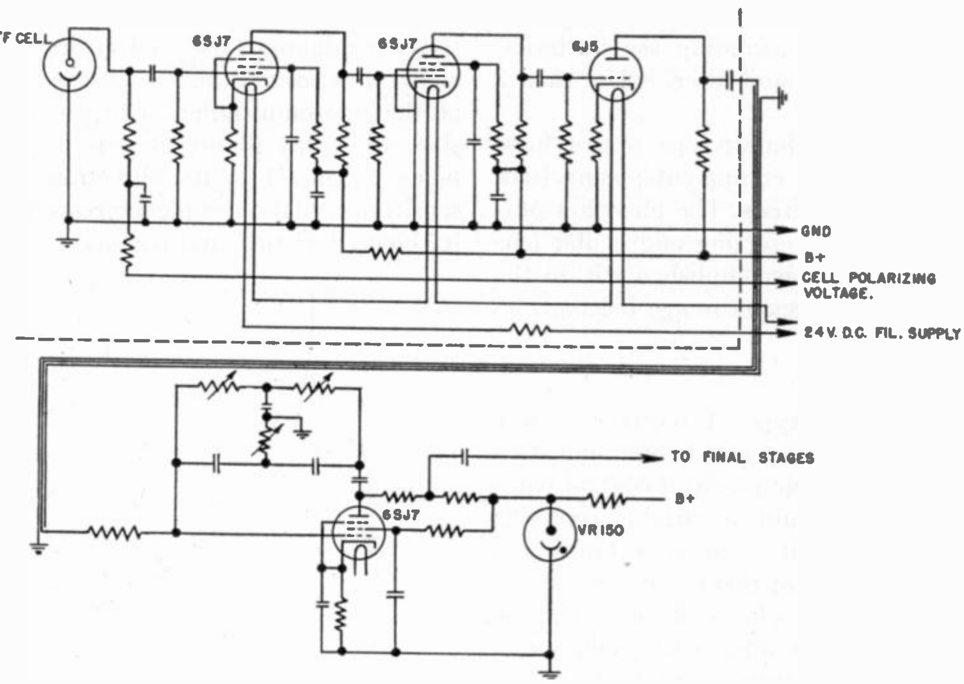

Fig. 17—Amplifier circuit for code-communication receiver using TF cell.

production-line assembly methods. The first three stages form the preamplifier. Selectivity is effected in the first stage of the main amplifier by a parallel-T feedback bridge. This stage also acts as a pentode limiter and is designed so that it saturates with a signal equivalent to approximately 3 times minimum detectable signal (approximately 15 microvolts at first stage) on the photocell. The purpose of limiting is to prevent blocking the receiver from the receiving ship's own radiator when transmitting, and to increase code speeds at high signal levels by effectively limiting the time constant of the selectivity network.

After this selective limiter stage, the low-frequency signal is fed to the signal-presentation system, which includes a keying stage that effectively keys a 1000-cycle-per-second local phase-shift oscillator, so that, when finally amplified by a power stage, the low-frequency code pulses appear as a 1000-cycle tone, which is more pleasing to the ear and a frequency to which the ear is more responsive. Visual presentation is also provided by a neon lamp.

Obtaining very low noise level with freedom from microphonics under conditions of vibration has limited the choice of a suitable tube for the first amplifier stage to a few types. The 6J7, 6SJ7, 9002, and lighthouse types have been used, but in most cases careful selection is necessary to obtain tubes suitable for this application. There is a distinct necessity for work to be undertaken to make available a suitable tube for this application which would have a low noise level, low microphonics, and a rugged construction to meet the rigid needs for high-gain amplifiers in a number of naval applications.

An input circuit used with the TF cell for a voice-modulated system is shown in Fig. 18. This circuit has the same low noise level as the circuit of Fig. 17, but offers the advantages of higher input impedance for the cell at audio frequencies and allows the use of alternating current on tube heaters. Because of the large feedback factor in this circuit its gain is slightly less than unity, so that the circuit is equivalent to a cathode follower and offers a very high input impedance to the cell; but being connected in conventional amplifier fashion it allows the cathode to be grounded, which is necessary for alternating-current operation of the heaters.

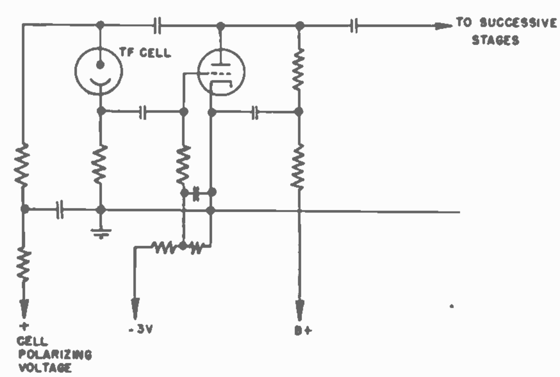

Fig. 18—Input circuit for TF cell.

Conclusions and Acknowledgments

The authors have attempted to present some general aspects of light-wave-communication devices developed for naval use, with certain technical details where it was felt they would be of particular interest to the electronic engineer.

The infrared devices described in this paper represent the untiring effort of many scientists and engineers, and the authors make no claim to originality for any of the material presented. Acknowledgment by individuals would entail an endless list of names and would

most likely omit some or give undue credit to others. Rather than this, it is considered more appropriate to list the organizations most directly concerned with various phases of the entire program.

Such a list would include:

Under the National Defense Research Committee:
- Brooklyn Polytechnic Institute
- Harvard University
- Northwestern University
- Ohio State University
- University of Michigan
- University of Rochester

Commercial Organizations:
- American Gas Accumulator Company
- Cover Dual Signal Systems, Incorporated
- Crouse Hinds Company
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- Farnsworth Radio and Television Corporation
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- Polaroid Corporation
- Radio Corporation of America
- Sampson United Corporation
- Wakefield Brass Company
- Westinghouse Electric Corporation

Naval Organizations:
- Bureau of Ships Test Station, Fort Miles, Delaware
- Naval Research Laboratory, Physical Optics Division
- USS CALLAO (IX205) Experimental Ship
- USS MARNELL (PYc39) Experimental Ship
- Bureau of Ships. The authors wish particularly to thank the group of engineers in the Bureau concerned with this program, some of whom assisted materially in the preparation of this paper.

A Wide-Band Directional Coupler for Wave Guide*

H. C. EARLY†, ASSOCIATE, I.R.E.

Summary—**The frequency range over which most types of directional couplers will operate is rather limited. This is especially true of wave-guide couplers, since the impedance of the guide changes with frequency. A new type of coupler is described which uses a small loop that responds to both the electric and the magnetic fields. When used in conjunction with a special section of ridge wave guide, it is possible to obtain excellent directional characteristics over a two-to-one frequency range.**

Introduction

When electrical measurements are to be made at microwave frequencies, it is often desirable to employ a directional coupler. This device is attached to a wave guide or a coaxial line and will respond to either the forward wave or the reflected wave. Since radio-frequency transmission lines in general are not "flat" and have a standing wave which is caused by reflections, a directional "pickup" has a number of advantages in various applications.

1. One advantage is that its response is independent of its position with respect to the maxima and minima of the standing wave in the guide, and it is possible to measure power without having to locate maximum and minimum readings by means of a sliding probe.

2. It is useful as an indicator when adjusting the impedance of a load to match a radio-frequency transmission line. If the coupler is oriented to respond only to the reflected power, then it is easy to "tune" the load until the reflection is a minimum.

3. When a transmission line is carrying "pulsed" or modulated power, a directional coupler is used in making spectrum measurements. A simple capacitance probe is usually not suitable for this purpose because of the standing wave. For certain side-band frequencies the probe will be at a standing-wave maximum while for other side-band frequencies it will be at a minimum, so that it does not furnish a true sample of the radio-frequency spectrum which is being transmitted. The directional coupler does not have this limitation.

Several types of couplers of this sort which have excellent directional properties have been developed. The main limitation is the frequency range over which they will operate. This is especially true for wave-guide couplers. One type of coupler which has proved very satisfactory from a bandwidth standpoint is shown in Fig. 1(a). It consists of a small loop, the ends of which are connected to two 50-ohm lossy cables. If correct design relations are maintained, the power in lossy cable *A* will be proportional to the power in the forward wave in the guide or coaxial line, while the power in lossy cable *B* will be proportional to the power in the reflected wave. For large sizes of wave-guide, this coupler is especially advantageous since it occupies a relatively small space.

Principle of Operation

A rough idea of the operating principle can be obtained from Fig. 1(b). An electromagnetic wave in the

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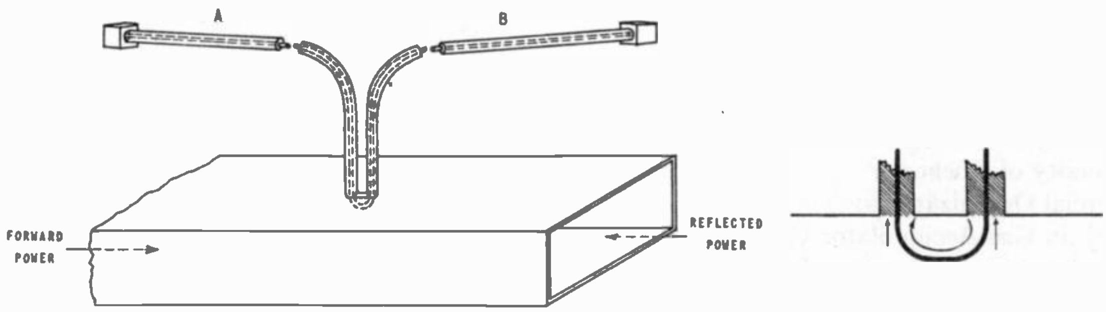
† University of Michigan, Ann Arbor, Mich.

guide will generate currents in the cables A and B because (1) the loop acts as a capacitance probe and responds to the passing electric field, and (2) the time-changing magnetic field of the passing wave links the loop and generates a voltage.

and are in series as far as this circuit is concerned. The impedance in the circuit is chiefly resistive and the current will be nearly in phase with the generator voltage or nearly 90 degrees ahead of the voltage in the wave guide. The angle α is caused by the self-inductance



(a) (b)

Fig. 1(a)—Position of coupling loop with respect to wave guide. (b)—Instantaneous directions of the currents in the loop caused by a passing wave.

of the loop. The dotted vector I_b indicates that the currents induced in the two cables will be of opposite directions.

The instantaneous direction of the current due to the electric field is the same at both ends of the loop while the current in cable A due to the magnetic field is opposite in direction to that in cable B (Fig. 2). For the "forward wave" in the guide these currents will tend to cancel in cable B and to add in cable A, while for the reflected wave there will be currents that cancel in A and add in B.

Fig. 3 shows the corresponding equivalent circuit for the electric field. The generator in this circuit has a voltage proportional to the electric field in the guide. C_1 represents the capacitance between the loop and the opposite wall of the guide; C_2, that between the loop

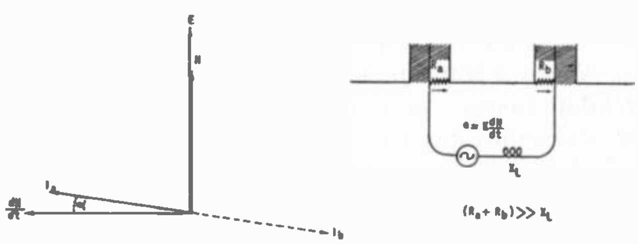


Fig. 2—Equivalent circuit for currents due to magnetic field in wave guide.

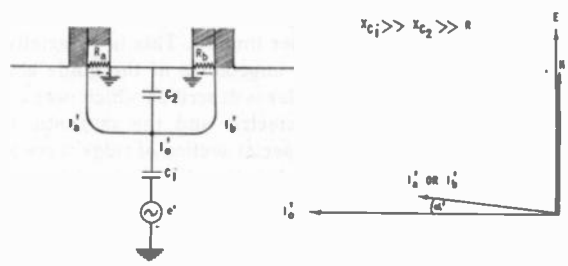


Fig. 3—Equivalent circuit for currents due to electric field in wave guide.

Phase Relations

The phase relations are not quite so simple as the above discussion would indicate. When a traveling wave passes the loop the maxima of the E and H fields both occur at the same instant, but the fact that the voltage due to dH/dt is 90 degrees out of phase with the voltage due to the E field would seem to prevent effective cancellation. The vector diagram, however, will show that this is not the case.

Since this is a linear system, the two voltage sources and their equivalent circuits can each be considered separately and then the two can be superposed to find the resulting effect.

Fig. 2 is an equivalent circuit and vector diagram for the currents due to the H field. The circuit contains a generator having a voltage proportional to the dH/dt and an internal impedance X_L which is due to the self-inductance of the loop. The resistances R_a and R_b represent the characteristic impedances of the two cables

and the adjacent wall. In this circuit the two resistances R_a and R_b are in parallel. Since the impedance due to C_1 is very much higher than the other impedances in the circuit, the current I_o' will be very close to 90 degrees ahead of the generator voltage. The angle α' between I_o' and I_a' is caused by the shunting effect of the capacitance C_2.

From these two vector diagrams it can be seen that the currents in R_a due to the two generators will either be in phase or else 180 degrees out of phase. The same is true for R_b. For a wave traveling in a given direction there will be cancellation in one of the cables if the vectors are equal and opposite. These relative magnitudes can be adjusted by changing the area or shape of the loop or by adjusting the width of the conductor from which the loop is made. Then the angles α and α' can be made equal by adjusting the value of C_2.

For satisfactory directional properties the following relations must be maintained:

(1) The loop dimensions must be small compared to a quarter wavelength.

(2) The ends of the loop must each be terminated in a pure resistance (such as 15 decibels of lossy cable).

(3) The loop must be small enough so that the reactance due to its self-inductance is small compared to the characteristic impedance of the cables.

(4) The geometry of the loop must be such that the current caused by the magnetic field in the guide or coaxial line has the proper phase and magnitude with respect to the current caused by the electric field.

Frequency Sensitivity

For wide-band operation of this directional coupler the ratio of the electric to magnetic fields in the wave guide must remain substantially constant. When the coupler is used with ordinary rectangular wave guide, the variation of guide impedance with frequency is the limiting factor as far as bandwidth is concerned. Fig. 4 is a curve showing how the guide impedance changes as the frequency is varied. $Z_{o\infty}$ is the guide impedance at infinite frequency and f_c is the cut-off frequency of the guide. In the ordinary range of operation of rectangular wave guide the ratio f/f_c varies from perhaps 2 to 1.1 and the wave impedance varies by a factor of 2, so that a directional coupler is limited in bandwidth.

One way to overcome this limitation is to install the coupler in a short section of guide having a greater width than the regular guide, and connected to the regular-size guide by tapered sections. Then the ratio f/f_c will be increased and the impedance variation over the desired frequency range will be decreased. However, this system is physically awkward, and there is likely to be trouble from other modes in the extra-wide section of guide.

A better method is to use a section of ridge wave guide as shown in Fig. 5. If the ridge is properly tapered at each end, it will not cause appreciable reflections in the guide. At the center of this ridge section the cut-off wavelength can be made three or four times the normal value without trouble from the TE_{20} made, and if the probe is placed at this point, the directional properties will be very satisfactory over a wide frequency range. The probe does not need to be centered with respect to the width of the guide, but can be moved toward the edge to keep it clear of the ridge.

The vector relations given in Figs. 2 and 3 are not sensitive to frequency changes. In Fig. 2, the angle $\alpha = \arc\tan\ (\omega L/(R_a+R_b))$ and in Fig. 3, the angle $\alpha' = \arc\tan\ ((R/2)\omega C_2)$, so that both angles increase with frequency at the same rate. If the angles α and α' are equal at one frequency, they will still be equal at other frequencies. The requirement that X_{C_1} be very large compared to the parallel resistance of the two cables is easy to meet, since X_{C_1} is of the order of 3000 ohms and the resistance of R_a and R_b in parallel is 25 ohms.

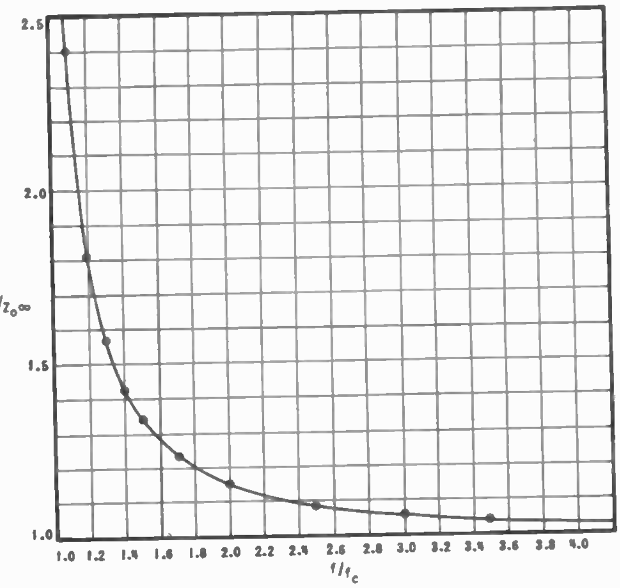


Fig. 4—Variation of guide impedance with respect to cut-off frequency. Ridge wave guide reduces this variation by moving the desired frequency range to the flat portion of this curve.

As far as the magnitudes of the vectors are concerned, the currents due to both the E and H generators increase directly with frequency, so the directional properties are maintained while the response for a given field strength increases. For many purposes this latter type of frequency sensitivity is not objectionable, but if required, the attenuation of the cables can be made to compensate for the change in probe response. This has been discussed in another paper.[1,2]

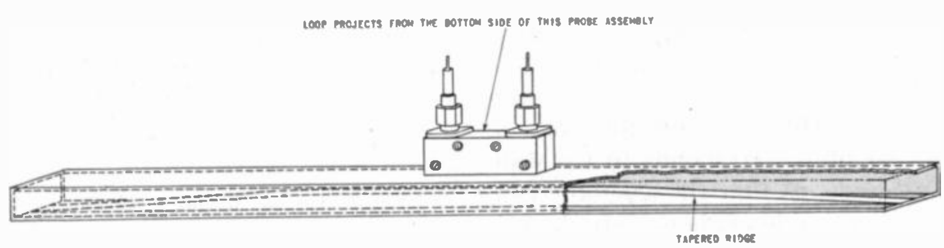


Fig. 5—Section of ridge wave guide. Both ends of ridge are tapered in such a manner as to minimize reflections.

[1] H. C. Early, "A wideband wattmeter for wave guide," Proc. I.R.E. vol. 34, pp. 803–807; October, 1946.

[2] Information regarding the design of ridge wave guide is given in a paper by Seymour Cohn entitled "Properties of ridge wave guide," accepted for publication in the Proceedings of the I.R.E.

Low-Frequency Model

The first coupler of this type was developed for use as a part of a direct-reading wattmeter for frequencies of about 500 megacycles where the wave guide had a cross section of 6 by 15 inches. The semicircular loop had a 3/8-inch radius and was made from brass strip 5/16-inch wide and 1/32-inch thick. It was supported by two type-N chassis connectors as shown in Fig. 6. The added capacitance C_2 is also shown in this drawing. A 15-decibel length of 50-ohm RG21/U cable was used for terminating each end of the loop.

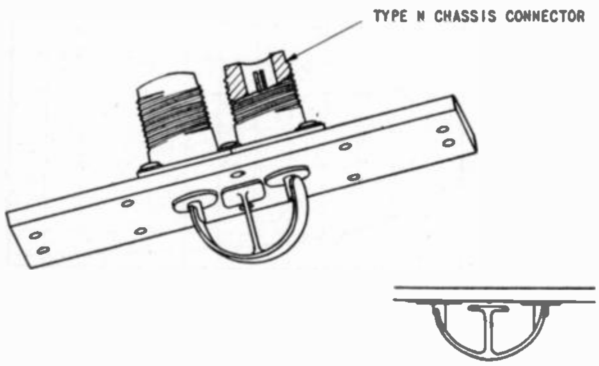


Fig. 6—Coupler for use in 6-inch by 15-inch wave guide.

Model for 3000 Megacycles

This is shown in Fig. 7. It was used in connection with a $1\frac{1}{2}$-inch by 3-inch wave guide and the directional properties were excellent over the entire single-mode range of this guide. It was found that the type-N fittings could not be used in this model since there were certain frequencies at which they introduced substantial reflections. The cables are not detachable from the probe assembly and the loop is soldered to the ends of the center conductors, so that there is no discontinuity in the cable dielectric or the diameter of the inner or outer conductors. The offset of 0.080 inch on the bottom surface of the probe assembly corresponds to the wall thickness of the wave guide, so that the assembly can be installed on the wave guide without introducing any unnecessary irregularities on the inside surface of the guide. The ends of the strap from which the loop is built are bent so that they increase the capacitance C_2 between the loop and the surrounding metal surface.

This model was used as part of a calibrated wattmeter. At these frequencies ordinary types of solid dielectric cable had a very erratic attenuation, especially when bent or moved. A type of RG21/U cable is manufactured in which the inside surface of the copper braid is silver plated. This cable is much better in this respect, and is therefore to be preferred if a calibration is required.

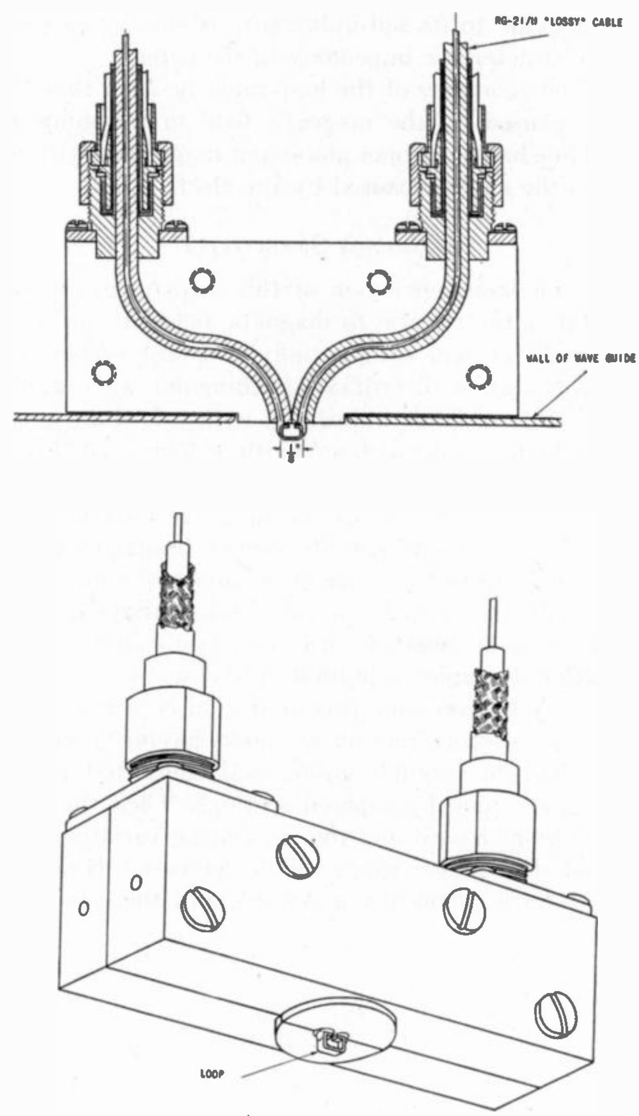


Fig. 7—Coupler for use in $1\frac{1}{2}$-inch by 3-inch wave guide.

Periodic Variations of Pitch in Sound Reproduction by Phonographs*

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Summary—**Causes of recurrent variations of pitch frequently encountered in the reproduction of phonograph records, commonly called "wow," are discussed. Considerations for the design of an instrument to measure the magnitude of these variations are given, minimum requirements and limitations of the design of such equipment are presented, and an instrument for use with 78-revolutions-per-minute turntables built to meet these requirements is described.**

Introduction

FOR MANY years phonograph records have been by far the most popular means of recording music and speech. Extensive efforts have been made by manufacturers of recording and reproducing equipment to render the reproduction as natural as possible.

In addition to the requirements of other reproducing or communication equipment as far as volume distortion, harmonic distortion, power-line hum, etc., are concerned, it is also necessary that all intelligence be reproduced at the original frequency. Although a slight shift of all frequencies can be tolerated as long as each frequency is changed by the same factor, it is important that the frequency ratios of all reproduced sounds are not disturbed and that the frequencies themselves do not vary during the time of reproduction. In other words, any frequency (or phase) modulation of the recorded signals due to the process of recording and reproducing should be avoided. In this paper, those causes of such modulation due to imperfections of the design of the turntable mechanism only will be discussed.

In addition to this frequency or phase modulation, amplitude modulation of the signal might be caused also by variations of the frequency response of the pickup over the range of these frequency variations, if the frequency characteristic of the reproducing pickup is not flat. This effect makes the occurrence of these disturbances even more objectionable to the listener, but it will be disregarded in this paper.

This described variation of frequency is commonly called "wow," and a number of papers have been published which discuss this subject.[1–6] A generally accepted definition of "wow" is given in an earlier issue of this publication.[7]

Causes of Wow

The causes of wow discussed in this paper can be classified into three groups: those originating in the turntable itself, those originating in the driving motor, and those originating in the driving mechanism necessary to transfer the motion of the motor to the turntable. In the first group, most variations of pitch can be traced to at least one of the following causes:

The turntable might be tilted from its correct position normal to the axis of rotation, or it might be warped, or its rim might be eccentric, oval, or irregular in shape. The latter cases are serious only when the turntable is rim-driven. It can be seen easily that an eccentricity of the rim-driven turntable produces variations of its angular speed, and these variations of speed produce phase or frequency modulation. The modulating frequency in this case equals the rotating speed of the turntable. Similarly, an oval rim-driven turntable will cause a modulating frequency of twice that of the turntable, and this can be generalized even further for other irregular shapes. These conditions can be treated by simple mathematics, and the results of such calculations are given in the appendix of this paper.

If the turntable is tilted from its normal position, the apparent angular speed of that point of the turntable on which the needle of the tone arm rests varies, because the normal distance of this point from the axis of rotation changes due to the inclination of the turntable. This variation in apparent speed also produces frequency modulation of the reproduced signal at twice the rotating speed of the turntable. In addition to this effect, it should be noted also that the needle point of the tone arm follows the up-and-down motion of the tilted turntable. The distance of the needle point from the tone-arm pivot is fixed, and, therefore, the needle point moves along a circle with its center in the pivot, rather than along a straight line parallel to the axis of the turntable. This causes a tangential motion of the needle point relative to the turntable. It can be seen easily that this relative motion produces phase modulation of the reproduced signal at a frequency of twice the speed of the turntable. This phase modulation adds to the variation of pitch described before, because these two effects are in quadrature. Obviously, the amount of this phase modulation depends also on the length of the tone arm and decreases with an increase of its length. A similar effect takes place when a relative motion between the center of the turntable and the pivot of the

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1 E. G. Shower and R. Biddulph, "Differential pitch sensitivity of the ear," *Jour. Acous. Soc. Amer.*, vol. 3, part 1, pp. 275–287; October, 1931.

2 T. E. Shea, W. A. MacNair, and V. Subrizi, "Flutter in sound records," *Jour. Soc. Mot. Pic. Eng.*, vol. 25, pp. 403–415; November, 1935.

3 R. R. Scoville, "A portable flutter-measuring instrument," *Jour. Soc. Mot. Pic. Eng.*, vol. 25, pp. 416–422; November, 1935.

4 E. W. Kellog and A. R. Morgan, *Jour. Acous. Soc. Amer.* vol. 7, p. 271; April, 1936.

5 W. J. Albersheim and D. MacKenzie, "Analysis of sound-film devices," *Jour. Soc. Mot. Pic. Eng.*, vol. 37, pp. 452–479; November, 1941.

6 H. E. Roys, "The measurement of transcription-turntable speed variation," Proc. I.R.E., vol. 31, pp. 52–56; February, 1943.

7 H. A. Chinn, "Glossary of disk-recording terms," Proc. I.R.E., vol. 33, pp. 760–763; November, 1945.

tone arm exists. This occurs, for instance, on certain inexpensive phonographs when one of these elements, or both, are shock-mounted. In practice, the last mentioned causes produce considerably less wow than the irregularities of the turntable rim.

Another factor which might influence the wow output of a phonograph turntable is the mechanical unbalance of the turntable itself. Even if the turntable is centered on its shaft and its plane is exactly normal to the axis of rotation, irregularities can be produced by the unbalanced forces if the center of gravity of the turntable is not in the axis of rotation. The effect of this unbalance depends very much on the design of the turntable bearings and is especially pronounced if the bearings are loose. This might, for instance, happen after an extended period of operation when the bearing surfaces are worn. The rigidity of the piece supporting the bearing also has an influence on the irregularities caused by unbalance. It is not possible to calculate this influence under general assumptions because of the differences of the details in the design on different turntables. The amount of unbalance which can be tolerated, therefore, has to be determined separately in each case.

The above-described causes can be remedied only by proper design and suitable manufacturing methods. There is no possibility of reducing the influence of the speed variations of the turntable itself on the reproduced signals. Fortunately, this is not the case with the irregularities produced by the turntable motor and by the drive connection between motor and turntable. It is customary to provide some resilient member as a portion of this drive. This resilient member, together with the mass and the inertia of the turntable, acts as a mechanical low-pass filter, and its cut-off frequency can be chosen so low that it is considerably lower than the lowest wow frequency, e.g., the frequency of the turntable rotation. The cut-off frequency of this filter is determined by the compliance of this resilient member and the moment of inertia of the turntable. The moment of inertia can be easily calculated from the dimensions of the turntable; the compliance of the resilient coupling link can be found best by experiment in most cases.

Due to this filter action, the influence of other wow-producing factors is much smaller than the irregularities of the turntable itself. In the driving motor an electrical or mechanical unbalance of the rotor, or eccentricity of the motor shaft, or of the driving pulley on this shaft, might produce a modulating frequency equal to the frequency of rotation of the motor. This frequency is approximately equal to the line frequency if a two-pole induction motor is used, and approximately equal to one half the line frequency with a four-pole induction motor. These causes of wow can be eliminated by careful design and manufacture of the motor.

The influence of the third group of irregularities, those originating in the driving mechanism which transfers the motion of the motor to the turntable, depends, of course, on its design. If gears are used to reduce the speed of the motor to the turntable speed, the frequency of rotation of intermediate gears might be one of the modulating frequencies; others are related to the number of teeth of each gear, their multiples, fractions, sums, and differences. Usually, only a few of these combinations are predominant over the rest, and in many cases their frequency is high enough to be damped out by the fly-wheel effect of the turntable.

Another possible source of disturbances is ball bearings, where the frequency of disturbance might be related to the frequency of the shaft through the number of balls.

If the turntable is rim-driven through an idler wheel which transmits the motion by friction between the motor pulley and the idler wheel on one side, and the idler wheel and the turntable rim on the other side, the frequency of rotation of the idler wheel might be one of the modulating frequencies, also. This is especially true if the idler wheel is eccentric, or if its circumference is irregular, or if the plane of the wheel is not parallel to the plane of the turntable. This design is used in most phonographs for home use, and it is customary to place a rubber tire around the idler wheel. Also, the aforementioned effects can occur if the elastic properties of the rubber tire vary along its surface, or if there are "bumps" on certain spots of the circumference.

It should be noted that all the disturbances under discussion are periodic but not strictly sinusoidal, but they can always be resolved into a Fourier series in which the fundamental frequency predominates.

The Wow Factor

The general considerations above raise the question as to how wow actually can be determined. But any quantity must first be defined before it can be measured, since the results of the measurement otherwise would be meaningless. From the equations given in the appendix, it seems to be most practical and simple to express the amount of wow present in a particular signal by its peak-frequency excursion given as a fraction or percentage of the average frequency. This definition would have the additional advantage that peak-reading instruments can usually be built more easily than those measuring average or root-mean-square values. On the other hand, for practical reasons it would be desirable to express wow in quantities of its "nuisance value," i.e., frequency fluctuations which sound equally objectionable to the average listener should be characterized by the same value of wow. Unfortunately, the physiological properties of the human ear do not seem to follow the desired simple relations, and additional research would be needed to produce a better definition of wow which also meets the physiological requirements. Shower and Biddulph[1] and Albersheim and MacKenzie[5] show that not only the amount of frequency deviation but also the frequency and rate of change of this frequency deviation, as well as the frequency and the level of the signal which is subjected to wow, have a bearing on this "nuisance value." Some authors propose to use a root-mean-square value of the frequency fluctuation rather than the peak value to characterize the amount of wow, but this opinion seems to be based on theoretical speculations rather than on experimental results. For these reasons, it is suggested that the peak value of the frequency variations be used, and a coefficient which may be called the "wow factor" shall be defined as the value of peak-frequency deviation expressed as a percentage of the average frequency of the signal.

Fig. 1—Front view of the wow meter.

Requirements for a Wow Meter

An instrument which is capable of measuring this wow factor without tedious computations should fulfill the following requirements:

1. It should produce a direct reading of the peak-frequency deviation, preferably directly in terms of per cent of the average frequency.

2. Its reading should not be affected by amplitude variations of a signal containing wow.

3. It should allow the use of an easily available signal source (for instance, a standard 1000-cycle test record for phonographs) and its range of operation should accommodate possible variations of the average rotating speed of the turntable.

4. It should have a "flat" response curve for all wow frequencies, i.e., modulating frequencies which are of interest. This means that, for domestic phonograph turntables which operate at 78 revolutions per minute, the frequency-response curve must be flat from less than 1.3 to at least 60 cycles per second. In this range the phase shift should be zero or, at least, proportional to the frequency, because peak readings are greatly affected by any phase shift of higher-frequency components. For commercial turntables with a speed of $33\frac{1}{3}$ revolutions per minute, the low-frequency range ought to be extended below $\frac{1}{2}$ cycle per second in a similar manner.

5. It is desirable that the relation between the value of the wow factor and the meter indication be linear by nature to facilitate calibration of the instrument. This is important, as it is rather cumbersome to produce signals containing exactly known amounts of wow for the calibration of a nonlinear instrument.

Design of a Wow Meter

An instrument designed to measure wow of phonograph turntables operating at 78 revolutions per minute and which meets these requirements is shown in Fig. 1. A block diagram is shown in Fig. 2.

Because the problem of measuring wow is essentially that of detecting the amount of frequency modulation of a low-frequency carrier, the obvious thought was to use the well-known limiter and frequency-discriminator circuits of frequency-modulation radio receivers. Actually, an instrument using one of these circuits has been described by Miner.[8] Unfortunately, all of these discriminators require tuned circuits, and the fact that a "carrier" of only 1 kilocycle is used makes it difficult to design them. To obtain the Q necessary for a satisfactory frequency response, iron-core inductors or transformers must be used whose inductance varies with the current. In addition, fixed capacitors are needed because no variable capacitors are available with a sufficiently high capacitance. Due to these two facts, it is not easy to tune these circuits to the desired frequency and to maintain this tuning adjustment. For this reason, a different system of frequency discrimination has been sought. It is described in detail in a later section of this paper.

An amplitude-limiting circuit is necessary to maintain the indication of the instrument independent of the amplitude of the input signal. A synchronized oscillator with fixed amplitude was found to offer greater advantages when a multivibrator is used than clipper circuits or a sufficient amount of automatic volume control. It can be easily synchronized by a single low frequency and produces a constant output voltage. The fact that its output is a square wave and not sinusoidal is an advantage for the discriminator circuit used.

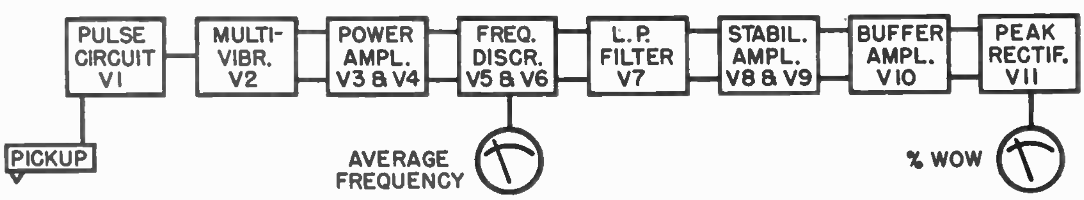

Fig. 2—Block diagram of the wow meter.

The output of this discriminator circuit contains the modulated and modulating frequencies, and a low-pass filter has to be used to suppress the former. The voltage produced by the modulating frequency is measured by a peak-reading vacuum-tube voltmeter consisting of a

[8] C. R. Miner, "Wow meter," *Gen. Elec. Rev.*, vol. 47, pp. 31–34; April, 1944.

stabilized amplifier, a conventional rectifier, and a meter. Fig. 3 shows the circuit diagram of the instrument. As may be seen from this diagram, the signal generated in the pickup of the phonograph is applied to the input terminals of an amplifier stage (V_1) which is overloaded under normal conditions to produce a flat-top output.

A differentiating circuit consisting of capacitor C_3 and resistor R_5 produces a fairly sharp pulse from this flat-top signal, and this pulse in turn is used to synchronize a conventional multivibrator (V_2) at the same frequency. Amplification of the output of this multivibrator by a stage of power amplification (V_3 and V_4) was necessary to produce a signal of sufficient current in the discriminator circuit. For reasons described later, an advantage was seen in using push-pull amplifiers throughout. The square-wave output of this power amplifier is applied to two capacitors (C_{12} and C_{13}) which charge and discharge each through a pair of diodes (V_5 and V_6). These four diodes are connected so that each capacitor charges through one and discharges through the other one of its associated diodes. Due to the push-pull excitation, one of these capacitors charges while the other one discharges, and vice versa. The two charging and also the two discharging diodes are connected in parallel, and each capacitor causes one current pulse per cycle of the input signal to flow through each of its associated diodes. Due to this parallel combination, and the push-pull signal, two pulses per cycle flow through the charging and also through the discharging diodes. This doubling of the signal frequency aids in filtering it from the other lower frequencies. Actually, this is a regular full-wave bridge-rectifier circuit, and the discharging current of one capacitor is the charging current of the other one at the same time.

The current due to each pulse equals the product of the voltage of the square wave produced by the power amplifier and of the capacitance of its capacitor, and the average current through the diodes is, therefore, proportional to the number of pulses and, thus, to the instantaneous frequency of the input signal. This current flows through a voltage divider consisting of resistors R_{21}, R_{24}, R_{20}, R_{27}, R_{26}, and R_{25}, and the voltage across this voltage divider is, of course, also proportional to the instantaneous frequency. The average current is proportional to the average frequency of the input signal, and a highly damped meter measuring this current could be calibrated in terms of cycles per second. An electrolytic capacitor of 1000 microfarads (C_{18}) produces sufficient damping.

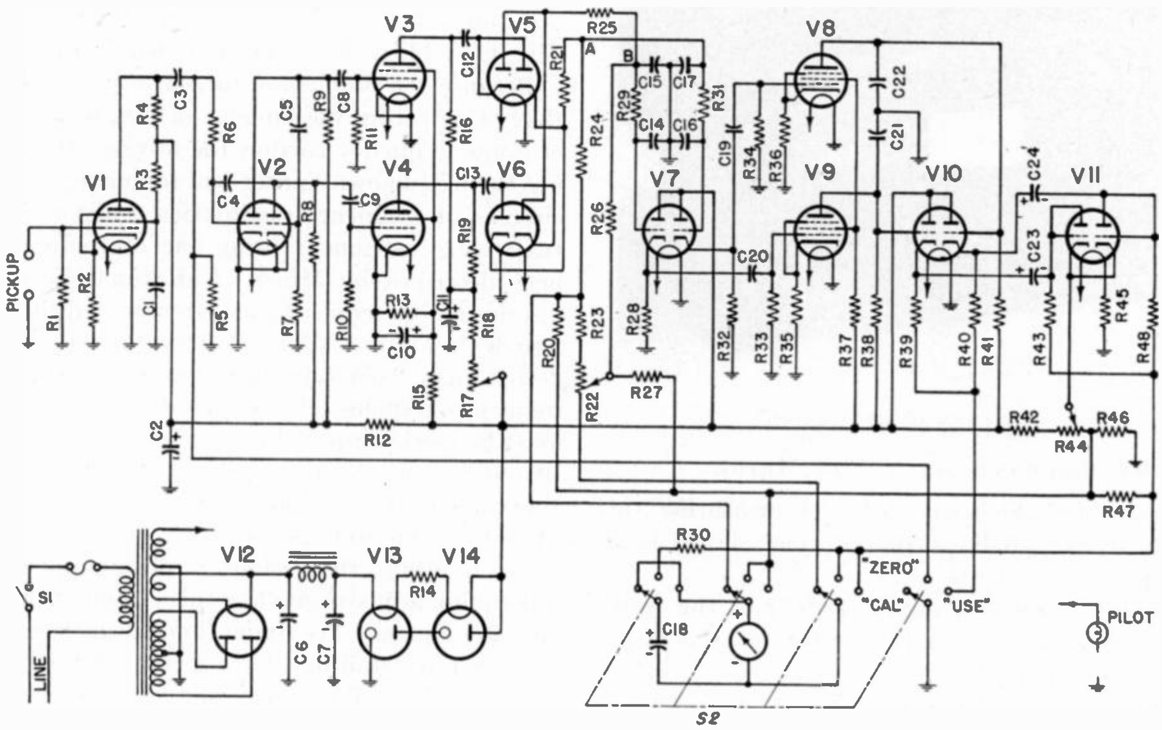

Fig. 3—Circuit diagram of the wow meter.

Obviously, if the average value of this voltage is proportional to the average frequency of the input signal, and the variations of this voltage are proportional in the same manner to the variations in frequency caused by wow, we can express these voltage variations as a percentage of the average voltage. Thus, we are able to measure the wow present in the input signal. This can be easily done by reducing the voltage of the square wave, and, therefore, the current through the diodes and the voltage divider, until a suitably shunted meter measuring its average value reads, for instance, full scale. To obtain this, a variable resistor (R_{17}) is connected in series with the power-amplifier tubes V_3 and V_4. An increase of this resistance reduces the voltage applied to these tubes and, therefore, also reduces the peak voltage of the square-wave signal produced in this stage. With the switch S_2 in the "CAL" (calibrate) position, the meter is connected across a portion of the above described voltage divider, and the shunt consisting of resistors R_{22} and R_{23} can be adjusted to the desired value to compensate for commercial tolerances of components in other parts of the instrument. This will be described later. This discriminator circuit is essentially a frequency meter similar to the one described by Hunt.[9]

The following signal components will be present between the points A and B of the voltage divider (see Fig. 3): a constant voltage proportional to the average current flowing through the diodes; low-frequency components caused by the variations of frequency of the original signal due to wow; and a group of frequencies of approximately twice the signal frequency, consisting of the frequency-doubled modulation products originally present in the signal containing wow. (These frequencies appear as pulses, and, therefore, also contain a large percentage of their harmonics.) The constant voltage is proportional to the average signal frequency, and the low-frequency components are proportional to the variations of the signal frequency. Therefore, their ratio equals the desired wow factor. The third group of frequencies is not wanted for the measurement of wow and must be suppressed by a low-pass filter before the amplitude of the low-frequency components can be determined. For this purpose, a balanced two-stage resistance-capacitance filter was used, consisting of the voltage divider, the resistors R_{29} and R_{31}, and the capacitors C_{14}, C_{15}, C_{16}, and C_{17}.

It was found necessary to connect a buffer amplifier to the output of this filter, and a twin triode (V_7) was used for this purpose connected as a double cathode follower. The output of this buffer stage is amplified by

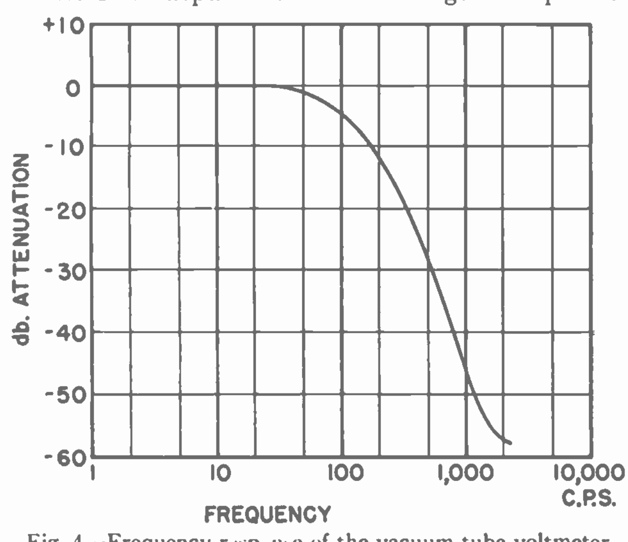

Fig. 4—Frequency response of the vacuum-tube-voltmeter section of the wow meter.

a push-pull high-gain amplifier (tubes V_8 and V_9), which is stabilized by feedback developed across the unbypassed cathode resistors. Due to the push-pull arrangement, a common screen series resistor could be employed which does not require any by-pass capacitor. This is a great advantage at low frequencies. At the same time, the tendency to "motor boat" is reduced and some in-phase feed-back is produced which aids in balancing the output of the amplifier.[10] The output of this amplifier was applied to another buffer amplifier (V_{10}), which is also connected as a double cathode follower. This was necessary to produce a signal at the low-impedance level needed for the peak-voltmeter rectifier tube (V_{11}). (A low-impedance level is required to obtain sufficient current in the indicating meter.)

Some difficulties were encountered in the design of this amplifier because of the low frequency at which it has to operate. High-grade oil capacitors of 12-microfarad capacitance were selected for the coupling capacitors C_{19} and C_{20}. The high-frequency response of the amplifier was further limited by the shunt capacitors C_{21} and C_{22}. The over-all frequency-response curve between the points A and B on the voltage divider and the push-pull output of the amplifier measured at the cathodes of V_{10} is shown in Fig. 4; this diagram shows that the unwanted frequencies near 2000 cycles are sufficiently attenuated, and that the response is "flat" up to approximately 60 cycles. This meets the requirements.

It was necessary to use electrolytic capacitors of 40 microfarads to couple the final rectifier to the stabilized amplifier, and considerable trouble was encountered due to leakage of these capacitors. This leakage produced excessive drift of the zero reading of the final meter. Fortunately, this drift was very slow and could be compensated during short periods by a bucking voltage developed across a portion of R_{44}; this resistor was adjusted so that the voltage drop across it was equal to the voltage drop developed across the rectifier load resistors R_{43} and R_{48} by the leakage currents. This adjustment also compensated for the contact potential developed in the diodes. To permit proper adjustment of R_{44}, a third position of the meter-selector switch S_2 was provided and marked "zero." In this position the condenser C_{18}, which is normally parallel with the meter, is discharged through R_{30} and disconnected from the meter circuit, so that the zero adjustment can be accomplished in a relatively short time.

Attempts were made to eliminate these large coupling capacitors by direct coupling, but without success. It was found that the circuit complications necessary to balance out the drift of the operating point of the tubes usually encountered in direct-coupled amplifiers were not worth the advantage of eliminating the 12-microfarad capacitors (C_{19} and C_{20}), as they did not cause much trouble. Unfortunately, no direct coupling was possible to eliminate the electrolytic capacitors C_{23} and C_{24} because they not only serve as coupling capacitors, but are also an integral part of the peak voltmeter. Their capacitance is determined by the time constant fixed by the low-frequency response of this voltmeter and by the resistance parallel to the rectifier (R_{43} and R_{48}) whose current is fixed in turn by the range of the indicating meter. It was because a direct indication of the wow factor was desired that capacitors of so high a capacitance were needed.

[9] F. V. Hunt, "A direct-reading frequency meter suitable for high-speed recording," *Rev. Sci. Instr.*, vol. 6, pp. 43–46; February, 1935.

[10] F. F. Offner, "Push-pull resistance coupled amplifiers," *Rev. Sci. Instr.*, vol. 8, p. 20; January, 1937.

Because the final amplifier has a constant gain, there exists a definite relation between the current through the voltage divider and the current developed by the output rectifier. The amplitude of the low-frequency components present between points A and B, which produce, say, full-scale deflection of the meter measuring the output current, expressed as a percentage of the current through the voltage divider, is also fixed. It is, therefore, only necessary to adjust the gain of this amplifier to obtain the desired full-scale reading. In practice it has been found simpler to add an adjustable meter shunt consisting of resistors R_{22} and R_{23} to produce full-scale reading of the meter in the "CAL" position, with a current through the voltage divider somewhat larger than calculated. This allows the use of components with commercial tolerances in the feedback amplifier. This meter shunt has to be readjusted only when tubes or other components of the amplifier are replaced. Because the wow factor is exactly proportional to the output current of the peak voltmeter, this adjustment may be made at one point of the scale only; a source of signals containing a known amount of wow is needed, and the meter shunt (R_{22}) is adjusted until the meter reads this known amount of wow after the instrument is calibrated for the average frequency of the signal. This average frequency need not be known.

The instrument is used in the following manner:

After a warming-up period, a phonograph pickup is connected to the input terminals. A standard 1000-cycle record is placed on the turntable and well centered, so that a minimum of wow is produced by the record itself. Test records with worn center holes should not be used.

The selector switch S_2 below the meter on the front panel (Fig. 1) is then set into the "CAL" position and the "calibrate" control adjusted until the meter reads full scale. Due to the long time constant of the meter and its parallel capacitor C_{18}, ten to fifteen seconds are required to make this adjustment. The selector switch is then set to the "ZERO" position and the "zero" control adjusted until the meter needle stays at zero. This, too, requires ten to twenty seconds. The selector switch can then be set to the "USE" position, and after the switching surge dies down, the steady deflection of the needle will indicate the wow factor. In the particular instrument described a full-scale value of 5 per cent wow was selected, and with some care readings can be duplicated within 0.1 per cent wow. It is unfortunate that the time constant of the instrument has to be that long, but this cannot easily be avoided, due to the low frequencies of wow. Despite this disadvantage, the instrument proved very valuable for checking the amount of wow present in phonographs and turntable assemblies.

Although this instrument was designed for phonographs with a speed of 78 revolutions per minute, there is no reason why a similar instrument for $33\frac{1}{3}$-revolutions-per-minute turntables could not be built, except that the difficulties encountered in the design of the amplifier and peak voltmeter would be increased due to the necessary extension of the low-frequency response.

Appendix

Symbols

In the following paragraphs a distinction is made between the quantities derived from the low-frequency motion of the turntable and those derived from the high-frequency recorded signal. The first group of values has been designated by lower-case letters, and the second one by capitals. The following symbols are used with this understanding:

a_n = eccentricity or other measure of geometrical irregularity of turntable, subscript indicating sections of appendix
c = constant peripheral velocity of rim-driven turntable
f = instantaneous frequency of turntable rotation
f_0 = average frequency of turntable rotation
$g_0, h_0, \cdots$ = average frequencies of wow-producing disturbances, other than turntable rotation
n = order of term in Fourier series, also number of irregularities per revolution of turntable
r = variable distance between irregular rim of turntable and its center of rotation
t = time co-ordinate
v = variable angular velocity of rotating turntable
α_n = phase angle in Fourier series for argument f_0 (see above), subscript indicating order of term
β = angle explained by Fig. 8
$\beta_n, \gamma_n, \cdots$ = phase angles in Fourier series for arguments $g_0, h_0, \cdots$ (see above)
θ = angular co-ordinate of turntable with irregular rim also tilt-angle of tilted turntable
ϕ = instantaneous phase angle of turntable rotation
A_n = Fourier coefficients expressing frequency f of rotation of turntable, subscript indicating order of term
$B_n, C_n, \cdots$ = like A_n, but for series with arguments $g_0, h_0, \cdots$, respectively (see above)
E = signal voltage at terminals of pickup in general case
E_n = like E, but subscripts indicating sections of appendix
F = instantaneous frequency of signal
F_0 = average frequency of signal
ΔF = peak value of difference between F and F_0
N = number of cycles of signal per revolution of turntable
R = average (nominal) radius of turntable
T = length of tone arm
W_n = wow factor, subscripts indicating harmonic causing it or sections of appendix
Φ = Instantaneous phase angle of signal.

First, let us consider the irregular motion of the turntable due to irregularities in the turntable itself, without investigating their actual causes for the time being. If we call the frequency with which the turntable rotates f, we can set up the following equation:

$$f(t) = f_0\left[1 + \sum_{n=1}^{\infty} A_n \cos\left(2\pi n f_0 t + \alpha_n\right)\right]. \qquad (1)$$

By multiplying with 2π and integrating equation (1), we obtain the total angle ϕ through which the turntable has rotated up to the time t:

$$\phi(t) = 2\pi f_0 t + \sum_{n=1}^{\infty} A_n/n \cdot \sin(2\pi n f_0 t + \alpha_n). \quad (2)$$

In the two equations, the first terms on the right side express the frequency of the turntable or the angle through which it would have moved, respectively, if no irregularities were present, and the second terms express these irregularities. Only periodical variations are considered whose period equals one average rotation of the turntable. This assumption enables us to express these variations in a Fourier series, where A_n means the amplitude and α_n the phase of each individual harmonic. (For convenience, we will start our considerations at such a time that α_0 equals zero.)

If we assume that N cycles of our signal are recorded on the record per revolution, we obtain the frequency F of our reproduced signal

$$F(t) = Nf = Nf_0\left[1 + \sum_n A_n \cos(2\pi f_0 nt + \alpha_n)\right]$$
$$= F_0\left[1 + \sum_n A_n \cos(2\pi n f_0 t + \alpha_n)\right]. \quad (3)$$

If we neglect all disturbances occurring more than once per revolution by breaking off our Fourier series after the first term, we obtain

$$F_1 = F_0(1 + A_1 \cos 2\pi f_0 t). \quad (3a)$$

This equation shows that the maximum frequency deviation equals

$$\Delta F_1 = F_0 A_1 \quad (4)$$

and we obtain our wow factor W_1 for this simplified condition

$$W_1 = \frac{\Delta F_1}{F_0} = A_1. \quad (5)$$

It is not practical to calculate a wow factor for the general case expressed by (3), due to effects of slight changes of the phase angles α_n on the peak value of the deviation, but additional information might be obtained by calculating a wow factor W_n due to the nth term of (3)

$$W_n = \frac{\Delta F_n}{F_0} = A_n. \quad (5a)$$

These wow factors are independent of turntable and signal frequencies. If $\Phi(t)$ is the total phase angle of the signal at the time t, we obtain from (2)

$$\Phi(t) = N\phi(t) = 2\pi F_0 t + \sum_n [A_n/n] N \sin[2\pi n f_0 t + \alpha_n]$$
$$= 2\pi F_0 t + \sum_n [A_n F_0/(nf_0)] \sin[2\pi(nf_0)t + \alpha_n]. \quad (6)$$

Then our signal E produced in the pickup will be proportional to

$$E \sim \sin \Phi t$$
$$= \sin\left[2\pi F_0 t + \sum_n [A_n F_0/(nf_0)] \sin[2\pi(nf_0)t + \alpha_n]\right]. \quad (6a)$$

The appearance of the modulating frequency (nf_0) in the denominator of the second term on the right side of (6) indicates that wow can be identified with frequency modulation of the reproduced signal similar to such modulation in communication applications. This is not the case, however, as conditions here are quite different from those in communication work; there we produce variable modulation of a constant carrier frequency, while here we obtain a constant modulation of a variable "carrier" frequency, our signal. It should be pointed out that we may obtain formally phase modulation or any other kind of angular modulation which has no particular name, if we use a different definition of the coefficients A_n in the Fourier series. Actually, this is of no real importance, as the modulation frequencies and their amplitudes are fixed by the mechanical and geometrical properties of the turntable, and their effects on the signal do not depend on the names or equations used to describe them.

In the same manner, other periodic disturbances can be treated, such as those originating at the motor or the driving mechanism. We would have to make one additional Fourier series to (1) and (2) for each source of

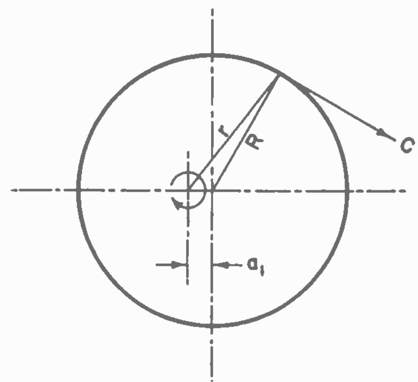

Fig. 5—Eccentric, round turntable.

disturbances of another basic frequency. We use another set of Fourier coefficients B_n, C_n, $\cdots$ and phase angles β_n, γ_n, $\cdots$ for each new series, and note that the new fundamental frequencies g_0, h_0, $\cdots$ are different from the frequency of rotation of the turntable f_0.

A number of simplified conditions will now be treated. Although they cannot be realized fully in practice, they are of interest because they show how the theoretical calculations can be applied to them.

1. Eccentric Turntable Rotating in Its Own Plane

We assume that a distance a_1 exists between the geometrical center of the circular turntable and its axis of rotation (see Fig. 5) and that it is driven at a constant peripheral speed; for instance, by a friction idler wheel making contact at the periphery of the turntable. Due to the varying distance of this point of contact from the axis of rotation, the instantaneous angular speed will also vary and will be inversely proportional to this distance. If we disregard the radial motion of the tone arm due to the spiral shape of the groove, the record will pass under the needle point of the tone arm with a velocity which is, in turn, proportional to the angular velocity of the turntable itself and, therefore, inversely proportional to the distance of the driven point of the periphery and the axis of rotation, provided the record is well centered in regard to the axis of rotation (and not in regard to the center of the turntable disc). If the peripheral constant velocity of the turntable is c, its radius

R, and its eccentricity a_1, then the angular velocity of the record will be proportional to c/r, the maximum velocity to $c/(R-a_1)$, and the minimum velocity to $c/(R+a_1)$. Then we can calculate our wow factor W_1 as follows:

$$W_1 = \Delta F/F_0 = \frac{\frac{1}{2}(F_{max} - F_{min})}{\frac{1}{2}(F_{max} + F_{min})} = \frac{v_{max} - v_{min}}{v_{max} + v_{min}}$$
$$= \frac{c/(R - a_1) - c/(R + a_1)}{c/(R - a_1) + c/(R + a_1)}$$
$$= a_1/R = W_1 \quad (7)$$

and the signal produced in the pickup

$$E_1 \sim \sin\{2\pi F_0 t + (\alpha_1/R)(F_0/f_0) \sin 2\pi f_0 t\}. \quad (7a)$$

The results of our calculations are approximate only, because we tacitly assumed that the distance r between the periphery of the turntable and its axis of rotation varies exactly sinusoidally, which is not really the case. Actually, this approximation will furnish us the same peak-to-peak deviation of the pitch of the signal. It is, therefore, permissible to use this simplified calculation and neglect the higher harmonics of this variation.

It should also be noted that, in practice, the turntable is always driven through a resilient member whose compliance, together with the inertia of the turntable itself, will tend to reduce the actual variations in angular speed or, in other words, impair the constancy of the peripheral speed. A wow factor smaller than the one calculated should, therefore, be expected in actual measurements.

Equation (7) also shows that an eccentricity of 0.025 inch will produce 0.5 per cent wow on a 10-inch turntable ($R=5$ inches). It is not impossible to maintain tolerances of considerably less than this amount of eccentricity in production.

2. Oval Turntable Rotating in Its Own Plane

To investigate the consequences of an oval turntable, we will assume that the turntable has the shape illustrated in Fig. 6 and is rotated around its center at a constant peripheral speed c and that the radius of the turntable r varies between the values $R+a_2$ and $R-a_2$ sinusoidally as a function of the angle θ (or, rather, due to the double periodicity of this function, of the angle 2θ). Then we obtain equations equivalent to (7) and (7a) by the same reasoning:

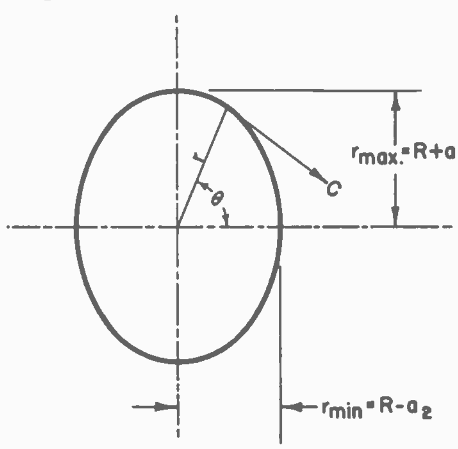

Fig. 6—Oval, rim-driven turntable.

$$W_2 = \Delta F/F_0 = \frac{c/(R - a_2) - c/(R + a_2)}{c/(R - a_2) + c/(R + a_2)} = a_2/R \quad (8)$$

and

$$E_2 \sim \sin[2\pi F_0 t + (a_2/R)(F_0/2f_0) \sin 2\pi(2f_0)t]. \quad (8a)$$

The same restrictions to the practical application of these equations exist which were found before for (7) and (7a).

3. Unround Turntable Rotating in Its Own Plane

The considerations developed in sections 1 and 2 of this appendix can also be applied to other types of irregularities, such as one occurring at three or four or more equally spaced points on the circumference of the turntable by substituting their linear dimensions in the current manner into (7) and the corresponding multiple of the frequency of rotation of the turntable into (7a), as was essentially done in (8) and (8a). In fact, we can generalize even further by expressing the shape of the turntable in polar co-ordinates as a Fourier series of the angle with a_1/R, a_2/R, a_3/R, etc., as the Fourier coefficients and α_1, α_2, α_3, etc., as the corresponding phase angles of this series. The signal E_{gen} developed in the pickup will then be expressed by

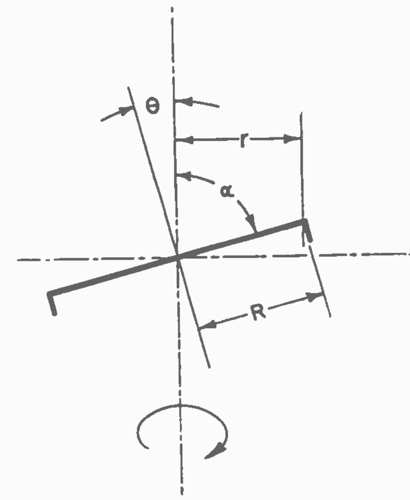

Fig. 7—Tilted turntable.

$$E_{gen} \sim \sin\left\{2\pi F_0 t + \sum_{n=1}^{\infty} (a_n/R)(F_0/nf_0) \cdot \sin[2\pi(nf_0)t + \alpha_n]\right\}. \quad (6b)$$

4. Tilted Turntable

We assume now that a turntable is tilted so that its perpendicular and the axis of rotation include an angle θ as shown in Fig. 7, and that the turntable is rotated at a constant angular speed. The velocity of a particular point on the record surface passing under the point of the pickup needle varies, then, proportionally to the perpendicular distance of the particular point from the axis of rotation; it will reach a minimum value twice per revolution of the turntable when the needle is in the plane of symmetry of the turntable and its axis of rotation and maximum values after 90 degrees of rotation from each minimum position.

Using again the method which furnished (7) before, we first determine the extreme values of the groove velocity and find

$$v_{max} \sim R$$

and

$$v_{min} \sim R \cos \theta. \qquad (9)$$

These two equations then furnish the following expression for the wow factor W_4':

$$W_4' = (R - R \cos \theta)/(R + R \cos \theta)$$
$$= (1 - \cos \theta)/(1 + \cos \theta) = tg^2 \frac{\theta}{2} \qquad (10)$$

and for the signal voltage E_4':

$$E_4' \sim \sin \left\{ 2\pi F_0 t + tg^2 \frac{\theta}{2} (F_0/2f_0) \sin 2\pi(2f_0)t \right\}. \qquad (10a)$$

This shows that this effect produces wow at a frequency of twice the frequency of rotation of the turntable. This deduction assumes that the point of contact between the point of the needle and the record grooves lies in a vertical plane through the axis of rotation. Actually, the needle point is restricted to move on the surface of a sphere (or along a circle in a vertical plane if the effect of lateral motion of the tone arm is disregarded) as shown in Fig. 8, and, therefore, it moves

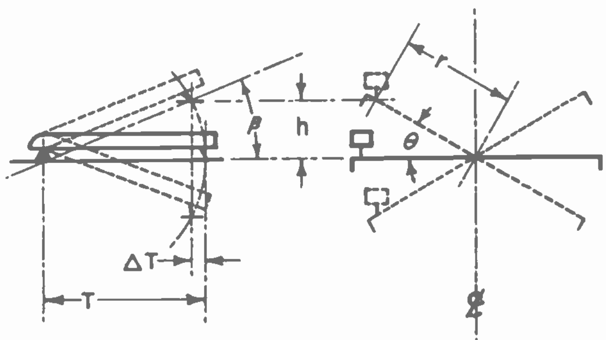

Fig. 8—Motion of tone arm caused by tilted turntable.

back and forth horizontally relative to the record. This relative motion causes an apparent lagging and advancing of the phase angle of the reproduced signal at a frequency of twice the frequency of rotation of the turntable and results in true phase modulation of the signal. Therefore, a different approach is required. This phase modulation is superimposed in quadrature over the frequency modulation calculated before, and can be of the same magnitude.

Fig. 8 illustrates the motion of the point of the tone-arm needle relative to the record when the plane of the record includes an angle θ with a plane normal to the axis of rotation. We see immediately that

$$h = r \cdot \sin \theta = T \sin \beta \qquad (11)$$

or

$$\sin \beta = (r/T) \sin \theta \qquad (11a)$$

and

$$\Delta T = T - T \cos \beta = T(1 - \sqrt{1 - (r/T)^2 \sin^2 \theta}). \qquad (12)$$

The relative motion of the tone arm over the distance ΔT can be approximated by the peak-to-peak phase excursion $2\Delta\phi_4''$ on the turntable, measured in radians:

$$2\Delta\phi_4'' = \Delta T/r = T/r - \sqrt{(T/r)^2 - \sin^2 \theta}. \qquad (13)$$

This, in turn, corresponds to a peak-to-peak phase shift of the signal of

$$2\Delta\Phi_4'' = 2N\Delta\phi_4''$$
$$= (F_0/f_0)[(T/r) - \sqrt{(T/r)^2 - \sin^2 \theta}]$$

or

$$\Delta\Phi_4'' = (F_0/2f_0)[(T/r) - \sqrt{(T/r)^2 - \sin^2 \theta}] \qquad (14)$$

to a phase angle Φ_4'':

$$\Phi_4'' = 2\pi F_0 t + (F_0/2f_0)[(T/r) - \sqrt{(T/r)^2 - \sin^2 \theta}] \cos 2\pi(2f_0)t$$

and to a signal E_4'' proportional to

$$E_4'' \sim \sin \{2\pi F_0 t + (F_0/2f_0)[(T/r) \qquad (15)$$
$$- \sqrt{(T/r)^2 - \sin^2 \theta}] \cos 2\pi(2f_0)t\}. \qquad (15a)$$

By differentiating (15) and dividing by 2π, we obtain the instantaneous frequency F_4'':

$$F_4'' = F_0\{1 - [T/r - \sqrt{(T/r)^2 - \sin^2 \theta}] \sin 2\pi(2f_0)t\} \qquad (16)$$

and from this equation the wow factor W_4'':

$$W_4'' = \Delta F_4''/F_0 = T/r - \sqrt{(T/r)^2 - \sin^2 \theta}. \qquad (17)$$

The appearance of the turntable frequency f_0 in the denominator of (14) and in corresponding places in (15) and (15a) does not contradict our statement that we are dealing with phase modulation. Rather, it is an accidental coincidence that the relative motion of the tone arm on the record is related to the turntable speed. If we would produce a similar relative motion of the tone arm by other means at another frequency, this other frequency would only appear as the modulating frequency in the argument of the cosine function of (15) and (15a) but not in the denominator instead of f_0. Thus we obtain, also formally, phase modulation.

From (10) and (17), we could calculate the total wow factor W_4:

$$W_4 = \sqrt{W_4'^2 + W_4''^2} \qquad (18)$$

but the resulting formula is too unwieldy for a practical use.

As an example, (10) and (17) will be applied to a turntable which is tilted by an angle $\theta = 10$ degrees away from its normal position. For this case, we obtain from (10) 0.76 per cent wow (W_4'). If we play a 12-inch record on the turntable using a 7-inch tone arm, we obtain from (17) for the outside grooves ($r = 6$ inches) 1.3 per cent wow, and for the inside grooves ($r = 2$ inches) 0.7 per cent wow (W_4''). The over-all wow factor will then be 1.5 per cent and 1.0 per cent, respectively. In practice, manufacturing tolerances for the angle θ can be maintained at considerably smaller values than 10 degrees.

Similar methods can be worked out to calculate wow factors due to other irregularities, and the results of these calculations can be used to specify manufacturing tolerances so that the wow due to each possible cause can be kept below the desired levels.

Acknowledgment

This paper is based on work executed in the laboratory of the Russell Electric Company, and the writer wishes to express his gratitude to Earle W. Ballentine, Executive Vice-President of this company, for his encouragement and interest; to Franklin F. Offner, of Offner Electronics, Inc., and Fritz Pordes, of Russell Electric Company, for their helpful suggestions in preparing this paper; and to Eugene T. Tippett, of Russell Electric Company, for his assistance in constructing and testing the described instrument.

The Effect of Q on Power-Amplifier Efficiency*

FRANKLIN F. OFFNER†, ASSOCIATE, I.R.E.

Summary—**With class-A operation, loaded-plate-circuit Q does not affect plate efficiency. With extreme class-C operation, Q has a considerable effect. A Q of 50 is required to keep loss in efficiency below 3 per cent. To obtain full benefit from the tank capacitor it must be connected directly from plate to cathode. Connecting the plate or cathode to a tap on the plate inductance results in lowered efficiency.**

THE LOADED resistance-reactance ratio[1] or "effective Q" of a power amplifier's plate circuit greatly affects its operation. Although an exact general analysis would be quite involved, a simple treatment accurately gives the effect of circuit Q in special cases and allows an insight into the effect of circuit modifications on the operation of power amplifiers not explicitly covered by the simple theory.

It will be shown that, when the plate-current flow is not sinusoidal, too low a tank-circuit capacitance will cause increased plate dissipation. Furthermore, a number of circuits commonly used have an effective Q considerably less than would appear from the tank capacitance employed. This results from the plate-to-capacitor path having a high impedance at harmonic frequencies.

The following treatment is especially concerned with plate efficiencies. Tank-circuit losses will, therefore, be assumed to be very small. Alternatively, the circuit resistances may be considered reflected as part of the load resistance. To obtain over-all efficiencies in any actual case, the circuit losses must be subtracted from the output as calculated below.

Let us first consider a class-A power amplifier, driven at the resonant frequency of the plate-tank circuit. Here, the alternating plate current is substantially sinusoidal, and thus contains but a single frequency. The plate tank will therefore act as a pure resistance to the plate current, no matter what the circuit Q. That is, in a class-A power amplifier the efficiency is independent of the plate-circuit Q.

Second, we will consider extreme class-C operation. Large plate-current pulses are assumed to flow for a very small portion of each cycle, so that the angle of operation approaches zero, as illustrated in Fig. 1.

Let E_b = the plate-supply voltage
- $E_{p\,min}$ = the minimum plate voltage
- $E_{b1} = E_b - E_{p\,min}$ = the "useful" plate voltage
- I_p = average plate current
- f = the frequency of operation
- $\delta q = I_p/f$ = charge passing through plate circuit per cycle
- p = power output per cycle
- P_o = average power input
- P_1 = average power input with infinite Q
- P_2 = average power output, including effect of Q.

Then, under the assumed operating conditions, and neglecting the effect of tank-circuit Q, the fractional efficiency eff$_1$ is given by

$$\text{eff}_1 = E_{b1}/E_b \tag{1}$$

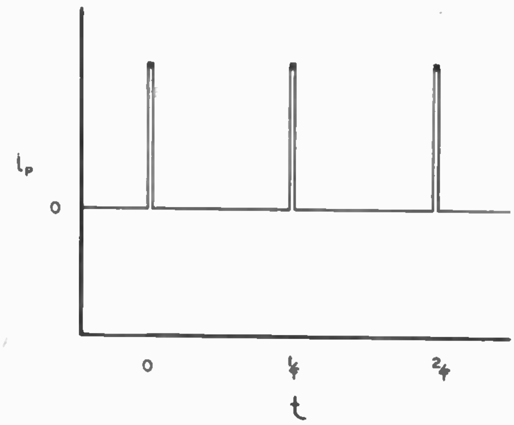

Fig. 1—Plate-current pulses in extreme class-C operation.

which approaches unity as $E_{p\,min}$ approaches zero. The dynamics of the circuit action will be as follows (Fig. 2): the plate current flows for such a short time that all the

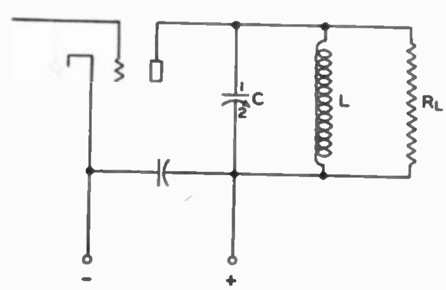

Fig. 2—Plate circuit of class-C amplifier.

charge δq passing through the plate circuit every cycle will flow into the tank capacitor C before any charge has flowed out through the tank inductance L and load resistance R_L. Thus, the maximum charge q_1 will reside on the capacitor at the end of each charging period, and $q_1 = CE_{b1}$.

During the remainder of the cycle, current will flow from plate 1 of C (Fig. 2), through L and R_L to plate 2 of C, and thence back through L and R_L to plate 1, thus completing the cycle. The final charge q_2 on the capacitor must for equilibrium conditions be less than q_1 by δq. The charge on, and potential across, C is illustrated in Fig. 3. Now the power stored by a capacitor is $q^2/2C$, and p, the power output per cycle, must be the difference between the power stored on the capacitor at the end and beginning of plate-current flow. Then

$$\begin{aligned} p &= (q_1^2 - q_2^2)/2C \\ &= [q_1^2 - (q_1 - \delta q)^2]/2C \\ &= (2q_1\delta q - \delta q^2)/2C \\ &= (2CE_{b1}I_p/f - I_p^2/f^2)/2C. \end{aligned}$$

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[1] Considering the load resistance in shunt with the coil and capacitor, $Q = R/X$. If it were assumed in series with the coil, it would be X/R.

The average power output P_2 is then

$$P_2 = fp = E_{b1}I_p - I_p^2/2Cf. \qquad (2)$$

The plate power input P_o is equal to I_pE_b, and the output, neglecting the effect of finite circuit Q, would, by (1), be

$$P_1 = I_pE_b\text{eff}_1 = E_{b1}I_p. \qquad (3)$$

The fractional loss in efficiency δeff, due to finite tank-circuit Q, is, from (2) and (3),

$$\delta\text{eff} = (P_1 - P_2)/P_1 = I_p^2/2CfI_pE_{b1} = I_p/2CfE_{b1}. \qquad (4)$$

Equation (4) allows the calculation of loss in efficiency resulting from the finite size of the tank capacitor, for the value of useful plate voltage and plate current. This may be put in terms of the effective Q. From the dynamics of the class-C amplifier,

$$P_1 = E_{b1}^2/2R_L.$$

Comparing with (3)

$$I_p/E_{b1} = 1/2R_L.$$

Putting this in (4) gives

$$\delta\text{eff} = 1/4R_LCf.$$

The effective Q is

$$Q = R_L/X_c = 2\pi R_LCf$$

so that

$$\delta\text{eff} = \pi/2Q. \qquad (5)$$

Thus, in the special case of an amplifier working at negligible angle of plate-current flow, the loaded-plate-circuit Q must be greater than about 50 if loss in plate

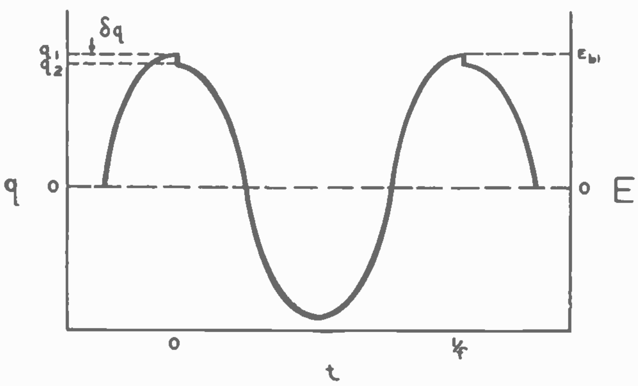

Fig. 3—Charge and potential on the plate capacitor.

efficiency due to the smallness of the tank capacitor is to be kept below about 3 per cent.

Some interesting general conclusions may be drawn from the above analysis. First, the power loss from insufficient effective Q is due to a change in the effective plate voltage during the time of plate-current flow, resulting in increased plate dissipation. This also indicates that, in calculating the effective Q, only the capacitance in essentially purely capacitive plate-cathode paths is to be considered. For, if appreciable self-inductance is present, the back electromotive force due to the sudden plate-current surges will prevent appreciable current flow in such a path during the brief period of current flow. Thus, all the circuits shown in Fig. 4 are inefficient; in (a), (b), and (c) the effective

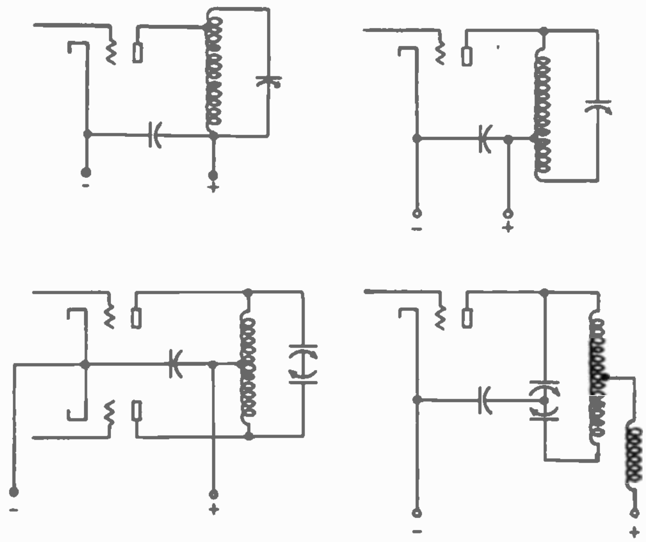

Fig. 4—Circuits in which full use is not made of tank capacitance.

capacitance approaches just the tube output capacitance, while in (d) only the upper half of the tank capacitor is to be considered in calculating the Q.

In the push-pull circuit of Fig. 5, each tube works into but half of the tank capacitor. But the plate current per tube is only half of the total plate current, so we may apply (2), (4), and (5) if by C we understand the capacitance of one capacitor section, and by I_p the plate current per tube.

In conclusion, we may note that the angle of plate-current flow has a great effect on the necessary loaded-circuit Q, the latter varying from approximately 50 to zero as the former varies from zero to 360 degrees. The calculation of efficiency at intermediate angles of plate-current flow and finite Q is considerably more difficult.

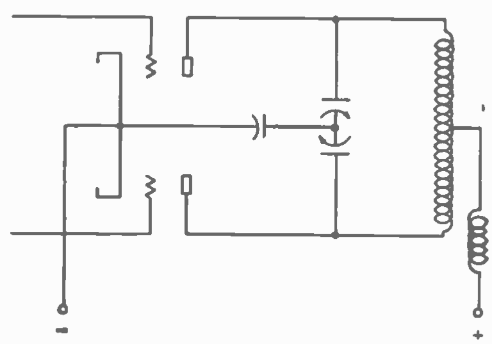

Fig. 5—Push-pull amplifier in which full use is made of tank capacitor.

However, the above simplified analysis both gives the actual efficiency in the two extreme cases and indicates circuit precautions to avoid needless losses. It should also be born in mind that, in general, tank-circuit losses increase as the tank capacitance increases. As shown above, the plate efficiencies of the class-C amplifier increases with the capacitance. Thus, a compromise value of capacitance will give best over-all efficiency.

A Practical Calculator for Directional Antenna Systems*

HOMER A. RAY, JR.†, ASSOCIATE, I.R.E.

Summary—Herein is described a calculator that will aid the engineer in finding two- and three-element antenna arrays to meet his specific need. It can be constructed in a small pocket size for field estimation in adjusting arrays or in the form of a large instrument for precise calculations in design work.

The operation of the machine in calculating ground-wave and sky-wave patterns is described, based on the radiation distribution of the various-height towers.

The procedure is continued through the determination of the actual field strength to be expected from the array at any point, as well as the root-mean-square field strength of the system.

The main idea is to proceed from the problem to the answer by the most direct method, while considering all the parameters.

THE OBJECT of this paper is to provide the broadcast engineer with a design for a two- and three-element antenna-pattern calculator that he can make himself and which is capable of high accuracy. The calculator was conceived both to meet the needs of the design engineer and to aid in the adjustment and operation of directional antennas by the field engineer.

The design of most three-element arrays involves a trial-and-error method which is most discouraging because of the large amount of calculating that must be done. The device to be described calculates both the ground-plane pattern and sky-wave patterns of two-and three-element arrays, and there is shown a method of arriving at the root-mean-square field strength of those arrays by graphic integration and comparison with the distribution of a single tower.

Complicated layouts have been eliminated and the mechanical construction lends itself to every-day hand tools. The machine has been divided into two parts, as is shown in Fig. 1. The first operation on the large scale at the left gives the amount and direction of the rotation of the field vectors at a distant point P while circumscribing the towers. This quantity is then added to the original phase angle of the relative loop currents of the towers on the smaller scale, and the vector sum of all the fields is read as a qualitative value.

Since the various functions are seen and handled individually on this calculator, it provides a perceptible conception of the parameters and a means for varying them to produce the desired results.

The calculator solves the equation

$$E_f = I + IR_2\underline{/\phi_2 + \psi_2 \cos\theta} + IR_3\underline{/\phi_3 + \psi_3 \cos(\theta+\beta)} \quad (1)$$

which is the polar form for the horizontal field, where

I = the current in the tower T_1

R_2 = the ratio of the current in T_2 with respect to T_1

R_3 = the ratio of the current in T_3 with respect to T_1

ϕ_2 = the phase angle of the current in T_2 with respect to T_1

ϕ_3 = the phase angle of the current in T_3 with respect to T_1

ψ_2 = the angular spacing of T_2 from T_1

ψ_3 = the angular spacing of T_3 from T_1

θ = the azimuth angle measured from the line T_1T_2 with T_1 as the origin

β = the angle made by the lines T_1T_3 and T_1T_2

E_f = the relative effective field.

A plot of E_f on polar paper for the various angles of θ will yield the familiar ground-plane pattern of the array.

The larger circular scale with the arms T_2 and T_3 solves the $\psi_2 \cos\theta$ of T_2, and the $\psi_3 \cos(\theta+\beta)$ of T_3. These angles are then added to the phase angles ϕ_2 and ϕ_3, respectively, on the smaller scales to the right, which consist of three vectors. The line between the centers of the circles represents V_1 from T_1 and is the reference vector of unity length and zero phase. The vectors V_2 and V_3 are the ratio arms of those circles. The above equation indicates a vector summation, and the sum of these vectors is E_f.[1]

Two drawings are required, and these are cemented to a base board. The large drawing is about ten inches in diameter with a protractor laid off around its circumference, clockwise. The inner circle is scaled off vertically from the line running through the center. Forty equal divisions are stepped off above and below this line to the edge of the circle. The scale applied to these divisions reads up from zero at the center to 200 degrees at the top, and down from 360 at the center to 160 degrees at the bottom. This scale may have greater or less range, or a number of scales may be included on it by the use of colored ink. Its range depends on the largest spacing usually encountered; 200 degrees will cover most cases.

The two overlapping protractor scales have the same radii, the lower being scaled counterclockwise with zero degrees at the bottom on the line through the centers. The upper is scaled counterclockwise with zero degrees at the top on this line through the centers. The centers of these circles are spaced a distance equal to their radii. A smaller circle has been drawn inside the main circle for ease in laying down a protractor scale, but the outer one has the radius equal to the spacing of the centers and is the one referred to when drawing the ratio scales, as follows. With dividers, step off twenty divisions from the center along the vertical radius of the upper circle. This is then calibrated from zero at the center to 1.0 at the top in 0.05 steps. The same is done in the lower circle, but at the 300-degree radius so as not to be confused with the summation scale which is drawn next. Mark these two scales "ratio."

The last scale (summation scale) is one of equally spaced arcs with their center at the center of the upper circle. The spacing of these arcs is the same as for the

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[1] Solution of mechanical operation is in Appendix I.

scales just laid down (twenty divisions to the length of a radius).

The scale is in 0.05 steps from the center of the upper circle, as zero, to 1.0 at the arc running through the center of the lower circle and continuing down to 2.0 at the bottom edge of the lower circle.

Two celluloid arms are mounted at the center of each circle so that they rotate freely but have high friction between themselves. This allows an angle to be set between them which will be retained when rotating them. A practical method of mounting is to drill the arms for a snug fit on a rubber grommet, which holds both together, and screw them down with a flat-head screw so that the taper of the head centers them, should there be any play between the screw and grommet. Longitudinal lines are scribed on all the arms running through the mounting centers. One of the large arms is T_2, and an arrow is added, as shown, to designate it as the index for the azimuth angle. One of the small arms on each circle may be the pointer arm and need have its longitudinal line only at its tip for reading protractor scales.

The two large arms and one each of the small arms have cross-hair sliders on them which are simply made by laminating celluloid strips of the same thickness as the arms. They need not run true or hold perpendicular, but must hold a point where they cross the longitudinal line. The machine is now complete and ready to be set up for a typical array.

Setting Up the Machine

Fig. 2 shows a typical three-tower array, which will be used as an example. The tower with the largest current is chosen as T_1 and either of the other two may be T_2 or T_3. The current in T_1 is taken as unity and the current in the others is expressed as a decimal of this current. The phase angle of the T_1 current is taken as zero and the other current phases are in relation to it, using positive angles. A lagging angle may be changed to a leading one by subtracting it from 360 degrees.

Place the T_2 arm at zero azimuth and set the cross-hair slider to indicate the spacing of T_2 from T_1 on the scale under the arm (130 degrees). Holding the T_2 arm at zero, move the T_3 arm to the angle β, the bearing of T_3 from the index line of the array. This angle must be measured counterclockwise from the line of zero azimuth on the array, which in this case is 240 degrees. Letting the T_2 arm rotate with it, turn the T_3 arm to zero azimuth and slide the cross hair to indicate the spacing of T_3 from T_1 on the scale (80 degrees).

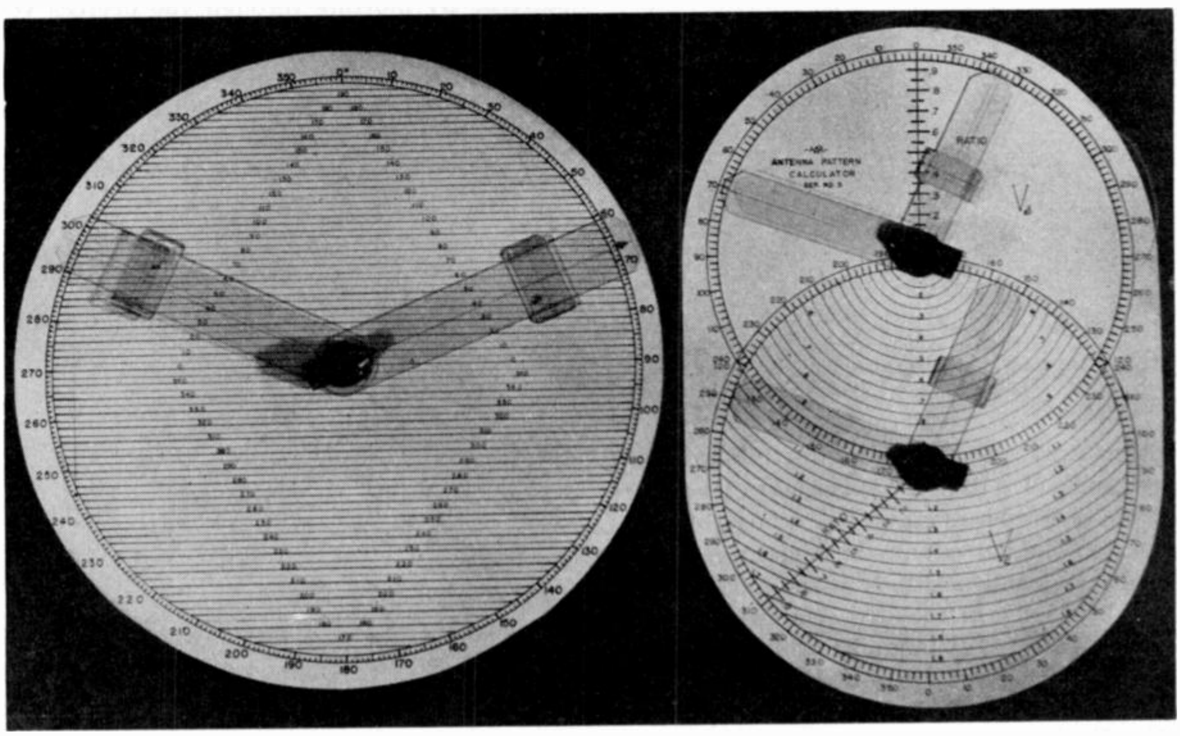

Fig. 1—The antenna field-pattern calculator. The left side computes the phase rotation and the right side computes the vector sum of the field-strength components around a directional array.

Set the small arms with the sliders, which will be called the ratio arms, over the scales marked "ratio," and move the sliders to indicate the ratios of the currents in their respective towers. V_2 will be set at 0.5 and V_3 will be set at 0.7. Next, the pointer arm of V_2 is set at zero and held there while the ratio arm is moved around the protractor scale to the angle which indicates the phase angle of the current in T_2 (270 degrees). The V_3 pointer is likewise held at zero degrees and its ratio arm rotated to indicate the phase in T_3 (90 degrees).

Operating the Machine

Set the arrow on the T_2 arm to the azimuth angle desired. Then set the pointer arm of V_2 to the angle read under the cross hair of the T_2 slider. Likewise, set the pointer arm of V_3 to the angle read under the cross hairs of the T_3 slider. The value of E_f is now the distance between the cross hairs of the V_2 and V_3 arms. This may be carried directly over to plotting paper with a pair of dividers, or measured with a convenient scale.

When only two towers are being considered the T_2 and V_2 arms are the only ones used, and the relative field strength is read directly on the scale under the V_2 cross hairs.

Sky-Wave Patterns

It becomes apparent from Fig. 2, which shows a plan of the three-tower array being considered, that the field

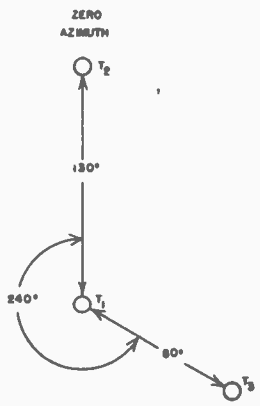

Fig. 2—A typical three-element array, where $R_2=0.5$, $R_3=0.7$, $\phi_2=270$ degrees, $\phi_3=90$ degrees, $\psi_2=130$ degrees, $\psi_3=80$ degrees, and $\beta=240$ degrees.

strength of this array, when looking directly down on it from a zenith angle of zero degrees, is the vector sum of the fields of the three towers using their relative original phase angles and the current in the respective towers only. Their spacings and positions in the field have no effect on the phase angle of the field vectors received or the sum of them. The above assumes that each tower has a point of radiation and that all these points lie on a horizontal plane. This can be assumed for practical considerations if all the towers are identical. In an array having all the towers in line and neglecting for the moment the vertical radiation characteristics of a single tower, summing up the field directly above the array and broadside to the array on the ground plane gives identical results. And procession from the line of the towers on the ground plane to broadside will give a plot of the sky-wave-field values for the azimuth angle in line with the towers, modified by the vertical radiation characteristics of the individual towers themselves. If all are identical towers, a factor may be applied to the sum of the fields.

To convert any array to an in-line array for a particular sky-wave pattern, consider the dotted lines in Fig. 3. T_2 and T_3 are moved over onto the line through T_1 having the azimuth angle for which the sky-wave pattern is desired (in this case, 330 degrees). They are moved perpendicular to this line and, therefore, assume a new spacing from T_1. The value of this new spacing is simply the value that was carried from the large circle to the smaller ones when computing the ground-plane field at azimuth angle.

On the machine, it amounts to the following. Set the index to the azimuth angle for which the sky-wave pattern is desired. Read the values under the cross hairs of both T_2 and T_3. In this case, T_2 gives 112 degrees and T_3 gives 289 degrees. Now swing the arms in line with each other and reset the sliders, respectively, to this new value. Either or both arms may point to zero or 180 degrees, depending on what the value is (T_2 will point to zero and T_3 to 180 degrees). Consider the index arrow to be pointing to zero degrees elevation and proceed clockwise or counterclockwise through 90 degrees, carrying the values from the T_2 and T_3 arms to the smaller circles for summation as in computing the ground-plane pattern. By plotting through 180 degrees you will be passing over the top of the array and down the other side to the ground plane again, thus giving the values for the opposite radial, also, with a single setup. These values must be multiplied by a factor $f(v)$ to get the true relative field strength at these elevation angles.

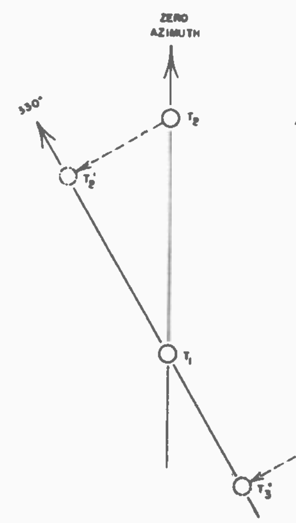

Fig. 3—The array of Fig. 2 with theoretical changes for computing the sky-wave pattern for the azimuth angle 330 degrees.

The radiation pattern of a single tower[1] is proportional to

$$E_1 = K \frac{\cos(G \sin\gamma) - \cos G}{\cos\gamma} \tag{2}$$

where γ is the elevation angle and G is the tower height. When γ is zero, the ground-plane radiation becomes

$$E_2 = K(1 - \cos G). \tag{3}$$

By expressing the vertical radiation field as a decimal of the ground-plane radiation field, that is, dividing the former by the latter, we obtain

$$f(v) = \frac{E_1}{E_2} = \frac{\cos(G \sin\gamma) - \cos G}{\cos\gamma(1 - \cos G)}. \tag{4}$$

(The values of $f(v)$ have been plotted in Fig. 4 for a number of tower heights.)

Evaluating the Pattern

The ground-plane pattern as drawn by the machine is simply the shape of the radiation from an array, and needs to have its various radii (that is, its size) scaled in millivolts per meter. The root-mean-square field strength of a pattern on the ground plane is described as that radius which is the root-mean-square of all the radii in the pattern. It can also be described as the radius of that circle which has the same area as the pattern.

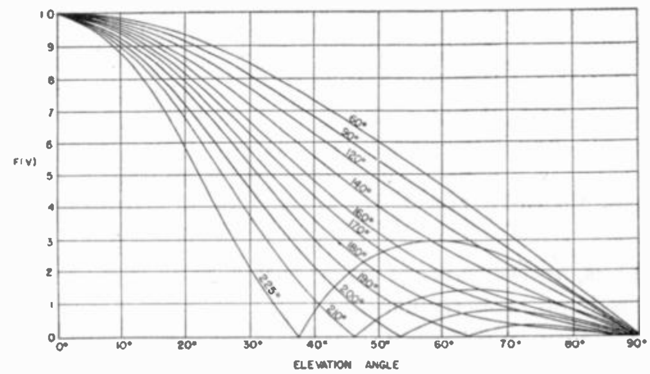

Fig. 4—A plot of $f(v)$ for modifying the values from the calculator to allow for antenna height in computing sky-wave patterns.

The above definitions show two methods of plotting the root-mean-square of the pattern over the pattern itself. A sufficient number of radii can be measured in inches or some convenient scale and a circle then drawn over the pattern having as its radius the root-mean-square of the selected radii of the pattern, or the area of the pattern can be measured in square inches with a planimeter or other means and a circle drawn over the pattern having the same area. It is the radius of this circle or the root-mean-square value of the pattern which we are going to evaluate in millivolts per meter.

The following procedure is used[2]: Draw the sky-wave patterns for every ten degrees azimuth around the array. There will be thirty-six patterns in all. In the same manner that the root-mean-square value of the ground-plane pattern was found, find the root-mean-square value for each of the elevation angles, from ten degrees through 80 degrees. There will be no radiation on the elevation angle of 90 degrees in tower arrays. This can be done, for instance at the elevation angle of 10 degrees, by taking the radius of each individual sky-wave pattern at the elevation of 10 degrees and finding their root-mean-square, or by finding the radius of that circle that has the same area as the pattern that would be drawn if these radii were plotted on polar paper as was the ground-plane pattern.

We now have eight root-mean-square radii, along with the ground-plane root-mean-square radius, with which we can plot a new sky-wave pattern which would be the average sky-wave pattern for the array. But rather than plot this we must first multiply each root-mean-square radius by $\sqrt{\cos\theta}$, where θ is the elevation angle for that particular radius. For instance, the ten-degree root-mean-square radius is multiplied by $\sqrt{\cos 10}$ degrees, etc.

We plot these, and the result is shown as $F_0(v)\sqrt{\cos\theta}$ in Fig. 5. The reason for $\sqrt{\cos\theta}$ being introduced is that, swinging a root-mean-square radius that is at an angle above the ground plane about the vertical axis, will describe a cone whose surface area is not a function

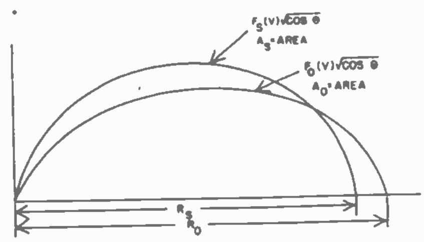

Fig. 5—The average sky-wave patterns of a quarter-wave antenna $F_s(V)$ and an array of antennas $F_0(V)$ multiplied by $\sqrt{\cos\theta}$, giving the power distribution.

of the length of the radius alone but also the elevation angle. By multiplying each radius by the square root of its elevation angle, the area described by this new radius will be solely dependent upon the length of the first radius alone and will be proportional to the power radiated at this elevation angle all around the array. In fact, the area A_0 under the curve $F_0(V)$ of Fig. 5 is proportional to the total power radiated by the whole array. And R_0 (the base of the curve) represents the root-mean-square value of the ground-plane pattern in relation to the area or power being radiated. Suppose we had another pattern with the same area which we knew was radiating 1 kilowatt of power, and knew also that at a distance of one mile the root-mean-square ground-plane field strength was 189.6 millivolts per meter. We would then consider the pattern under question as radiating 1 kilowatt of power and its radiation in millivolts per meter at one mile would be directly proportional to the ratio of its base (in inches) to the base of the known pattern.

For a practical example, in Fig. 5 is plotted the curve $F_s(V)\sqrt{\cos\theta}$. The $F_s(V)$ is the radiation pattern of a single, uniform-cross-section vertical tower a quarter-wavelength high. This pattern can be plotted directly from the values given in Fig. 4 on the curve 90 degrees. Multiplying these values by $\cos\theta$ and plotting in polar form gives the curve $F_s(V)\sqrt{\cos\theta}$ of Fig. 5. A theoretically perfect quarter-wave antenna over a perfect earth gives 196 millivolts per meter at one mile for one kilowatt of radiated power; or, for *practical* considerations, 189.6 millivolts if a two-ohm loss is assumed to represent the losses usually encountered in a practical installation. Thus we have the known antenna, whose area is taken to represent 1 kilowatt and whose base dimension R_s represents 189.6 millivolts per meter at one mile. In a geometrical figure, the lineal dimensions vary

[2] H. E. Gihring and G. H. Brown, "General considerations of tower antennas for broadcast use," Proc. I.R.E., vol. 23, pp. 311–357; April, 1935. A slightly different handling of the same procedure is given by F. E. Terman, "The Radio Engineers' Handbook," McGraw-Hill Book Company, New York, N. Y., page 782.

directly as the square root of the area; therefore, in making the volumes equal and directly comparing the bases of the two patterns, we have the proportions

$$\frac{F_0}{189.6} = \frac{R_0}{R_s} \times \sqrt{\frac{A_s}{A_0}} \tag{5}$$

where F_0 is the field strength at one mile for 1 kilowatt, in millivolts per meter, of the unknown array $F_0(V)$; R_0 is the base dimension of the unknown array (in inches); and R_s is the base dimension of the quarter-wave antenna (in inches). A_0 is the area in square inches of the pattern of the unknown array, and A_s is the area in square inches of the pattern of the quarter-wave antenna. Rearranging (5) we have

$$F_0 = \frac{\sqrt{A_s}}{R_s} \times \frac{R_0}{\sqrt{A_0}} \times 189.6. \tag{6}$$

$\sqrt{A_s}/R_s$, for a quarter-wave antenna, is found to be 0.5615 by measuring in Fig. 5. Therefore, the field strength in millivolts per meter at one mile for one kilowatt of power in the unknown array is

$$F_0 = 106.3 \frac{R_0}{\sqrt{A_0}} \cdot \tag{7}$$

This F_0 is the value of the root-mean-square field strength as defined in the first paragraph, under the heading "Evaluating the Pattern." By putting dimensions on the radius of this circle, which is laid down over the pattern itself, we have a yardstick whereby to measure the various radii of the whole pattern in millivolts per meter. The pattern then shows the millivolts per meter to be expected in the various directions from the array at a distance of one mile with no attenuation of the signal by the ground over which it travels, or what has been more commonly termed "inverse distance," meaning the signal falls off inversely proportional to the distance traveled due to its dissemination into space and the presence of a perfect earth. The actual signal at a mile and farther over various soils can be determined through the use of the set of charts which is a part of the Federal Communications Commission's "Standards of Good Engineering Practice," showing ground-wave field intensity versus distance. These are plotted over the range of the broadcast band and the extremes in soil conductivity.

Appendix

The mechanical solution of the calculator is shown in Fig. 6. The values of A and B are the quantities given by the arms T_2 and T_3, respectively.

A and B at all positions of the arm T_2 are given as

$$A = \psi_2 \cos \theta$$

$$B = \psi_3 \cos (\theta + \beta)$$

where β is the angle between the arms. The angles A and B are added to ϕ_2 and ϕ_3, respectively, through the use of the pointer arms by removing them from zero to these values of A and B (see Fig. 7). The ratio arms are IR_2 and IR_3 and now stand at the proper angles for vector summation. I is the vector of unity length and zero phase and is represented by the distance between the pivots of IR_2 and IR_3.

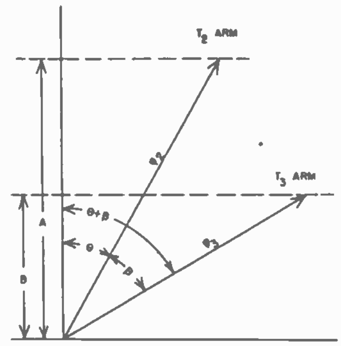

Fig. 6—Mechanical proof of the values given by the large arms T_2 and T_3 on the calculator. See appendix.

Thus, all the parts of the equation E_f have been considered and properly handled.

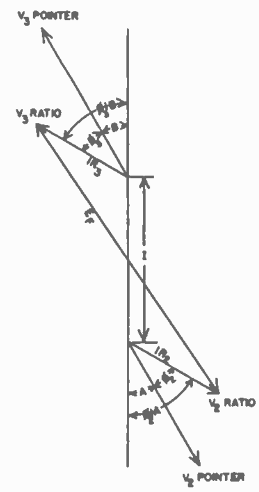

Fig. 7—Mechanical proof of the values given by the small arms V_2 and V_3 on the calculator. See appendix.

Conclusion

The calculator has been found to be a welcome aid in locating and adjusting nulls and loops in proposed antennas. The machine readily shows what parameters should be changed and in what direction to produce the desired results. Its accuracy depends upon the accuracy of the face layouts and the play in the pivots. If the machine is constructed on a large scale, its accuracy can be made to approach calculated values to a high degree.

Through the use of mechanical means for integrating the distribution of the radiation, as described, it is found that the accuracy of the results is quite sufficient for practical use, where the errors resulting from the exact determination of current distribution on the towers, the losses in the ground system under the array, the coupling equipment, and the instruments used for measuring the field are of a much higher order than will be introduced by a mechanical means of determining areas if care is used.

Magnetron Cathodes*

MARTIN A. POMERANTZ†

Summary—The multicavity magnetron imposes exceedingly severe requirements upon its cathode. Spectacularly high electron emissions have been observed under pulsed conditions. Cathode parameters are obtained by interpreting, in terms of the emission equations, data secured using rectangular microsecond pulses. Emission densities exceeding 50 amperes per square centimeter, limited only by sparking, have been attained, and several forms of current-versus-voltage characteristic may be identified. Sparking may be precipitated by phenomena originating either in the cathode or anode. Two competing mechanisms for cathode-initiated sparking have been established experimentally. The resistance of the oxide coating results in a pulse-temperature rise during the flow of high currents. Resistance values of 1 to 100 ohm-centimeters squared, deduced from measurements of this effect, agree with those obtained in experiments performed with cathodes having probes embedded within the coating. The secondary emission of oxide-coated cathodes varies with temperature in an exponential manner from approximately 4 to 7 at room temperature to 100 at 850 degrees centigrade for a cathode activated to the optimum. Magnetrons have been operated solely by secondary emission as a consequence of the back-bombardment of the cathode. Measurements have revealed that 3 to 20 per cent of the output power may be dissipated in this manner. Correlations have been established between magnetron performance and cathode emission. The high-current-mode boundary depends upon the available thermionic emission. Undesired emission from certain regions of the cathode may introduce losses. The life span of cathodes in magnetrons generally has been short, and all of the requirements for satisfactory magnetron cathodes have not been completely fulfilled by conventional types. A new type, the sinthor cathode, obviates the fundamental limitations inherent in prior varieties.

I. Introduction

RECENT developments in the field of electron emission have proved to be almost as spectacular as those relating to the principle of the multicavity magnetron. During the period immediately preceding the discovery of this new source of high-power centimeter radiation, research and development of thermionic emitting cathodes were not pursued as extensively as during earlier decades. The nature of previous applications has been such that factors other than the cathode (e.g., grid and anode design considerations) frequently have imposed the ultimate limitation upon transmitting-tube performance. Conditions of space-charge limitation generally prevail in receiving-tube operation, in which case emissions from oxide-coated cathodes of several hundred milliamperes per square centimeter are adequate. The techniques for the preparation of cathodes satisfying these requirements heretofore have been available.

However, the advent of the multicavity magnetron has, perforce, necessitated a revision of the cathode art. The cathode in this type of tube generally has become recognized as the limiting factor, and the requirements are increasing in severity as a consequence of the inevitable demands for operation at higher power levels. To appreciate the magnitude of the problem, one has only to realize that peak powers of megawatts are demanded of a structure of physical dimensions compatible with the generation of oscillations in the centimeter-wave band.

II. General Multicavity Magnetron Principle

Although it is not the purpose of this paper to present a detailed discussion regarding magnetron operation, a brief description is essential to an understanding of the role played by the cathode. Fig. 1 is a photograph of a typical magnetron having an indirectly heated oxide-coated cathode. (Photographs of actual cathodes are shown in Fig. 11). The anode *A* is a cylindrical copper block containing a central cylindrical

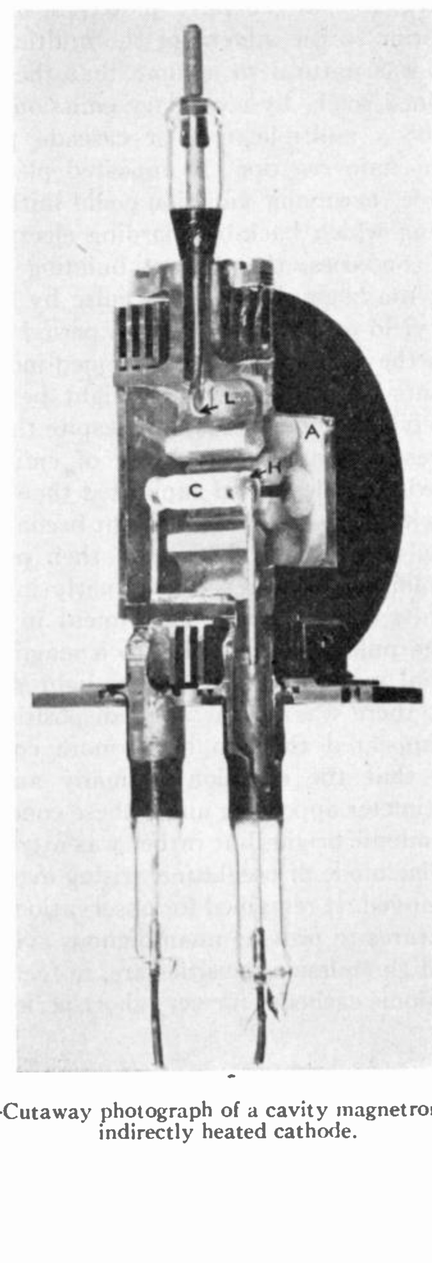

Fig. 1—Cutaway photograph of a cavity magnetron, showing indirectly heated cathode.

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cavity and a number of radial vanes. L is the output loop, whereas H represents two circular disks of metal at the ends of the cathode. The purpose of these shields or "hats" is, essentially, to prevent electrons from entering the end space.

The magnetron is placed between the poles of a magnet so that the magnetic field is parallel to the axis of the cathode, and short pulses of high negative voltage are applied to the cathode from a "modulator," the anode being grounded. Electrons emitted thermionically by the cathode are accelerated toward the anode during the duration of the square-top voltage pulse, and are acted upon by the magnetic field.

Under conditions which have been treated in detail elsewhere, oscillations will occur. This results in a gain of energy by some electrons, loss by others, and a back-bombardment of the cathode by electrons which may have acquired very high energies.

Even the earliest standard multicavity magnetrons were operated consistently at peak anode currents corresponding to emission densities of from 5 to 10 amperes per square centimeter, a value approximately 10 to 20 times as large as that generally quoted for oxide-coated cathodes prior to the advent of the multicavity magnetron. It was natural to assume that these currents were obtained solely by secondary emission, as a consequence of a multiplicative or cascade process resembling a chain reaction. It appeared plausible that the available thermionic emission could initiate oscillations, during which back-bombarding electrons would produce secondaries, the current building up in this manner at the beginning of each pulse by virtue of a secondary yield exceeding unity in a period short compared with the pulse duration. It seemed inconceivable that currents of this magnitude might be accounted for by purely thermionic emission, despite the fact that earlier investigations of the decay of emission from oxide-coated cathodes[1,2] had supported the expectation that somewhat higher emissions might become manifest in short pulses. The state of mind then prevalent is best exemplified by the reaction of early investigators to the results of an obvious experiment in which the high-voltage pulses were applied to a magnetron with zero external magnetic field. In the light of previous knowledge, there was a general predisposition to prefer what appeared then to be a more conservative hypothesis that the emission of many amperes per square centimeter appearing under these conditions was not of thermionic origin, but rather was attributable to some peculiar mode of oscillation arising even with the magnet removed. It remained for observations in simple diode structures to provide unambiguous evidence that extremely high emission densities are, in fact, available from thermionic cathodes for very short periods of time.

[1] J. A. Becker, "Phenomena in oxide-coated filaments," *Phys. Rev.*, vol. 34, pp. 1323–1352; November, 1939.

[2] J. P. Blewett, "Time changes in emission from oxide-coated cathodes," *Phys. Rev.*, vol. 55, pp. 713–718; April, 1939.

III. Techniques of Pulsed-Emission Measurements

The measurements of the fundamental thermionic-emission parameters of magnetron cathodes have been performed under a variety of conditions, both in magnetrons with zero applied magnetic field and in standard test diodes, several examples of which are shown in Fig. 2. Peak emissions are measured in a system

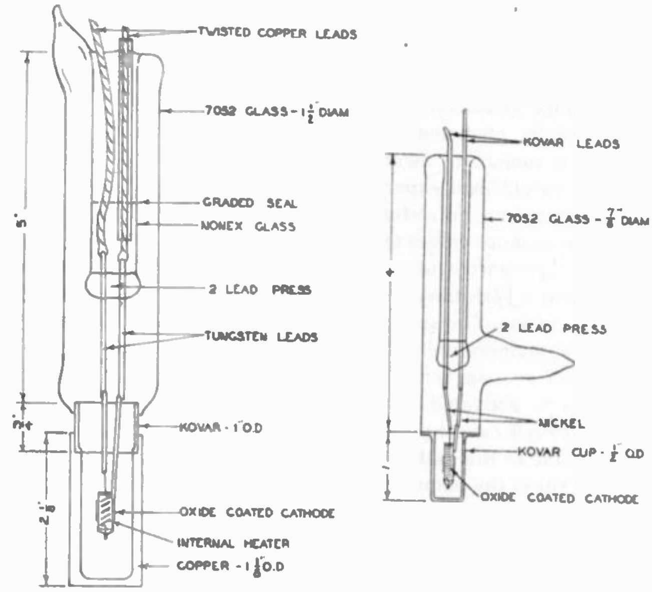

Fig. 2—Typical test diodes utilized in investigations of thermionic-emission properties of magnetron cathodes.

equipped with a "modulator," which is an apparatus arranged to produce rectangular microsecond pulses at various recurrence frequencies. Trigger circuits operating at rates as low as one pulse per second or as high as 4000 pulses per second have been utilized. The current measurement is observed by means of a synchroscope as the voltage drop across a noninductive viewing resistor, whereas the voltage is measured either with a capacitor divider or a resistor divider. The circuit is represented schematically in Fig. 3.

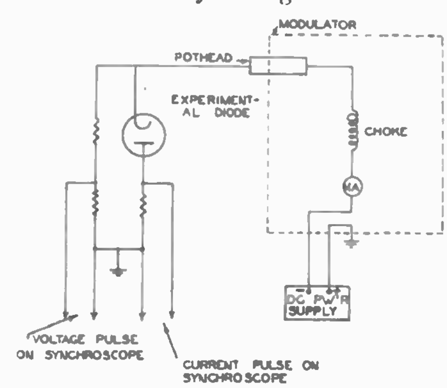

Fig. 3—Arrangement for obtaining pulsed emission data. The direct-current power supply is not used in general, but has a special purpose described in Section V.

The current versus voltage data thus obtained may be interpreted in terms of several well-known equations, namely the Richardson equation, the Langmuir-Childs three-halves-power equation, and the Schottky equation, which is applicable when the potential gradient at the cathode is not zero.

Various pertinent characteristics of a cathode become immediately evident from an examination of the current-versus-voltage data plotted on two-thirds-power paper. The three-halves-power law indicates that the space-charge-limited characteristic follows a straight line when plotted in this manner. Furthermore, the theoretical slope in the Langmuir-Childs equation may be computed by an evaluation of the constants, dependent upon tube geometry, for comparison with the experimental results.

IV. Pulsed Thermionic-Emission Characteristics of Oxide-Coated Cathodes

Fig. 4 is a typical diagram of the current versus voltage characteristics of a standard cathode processed

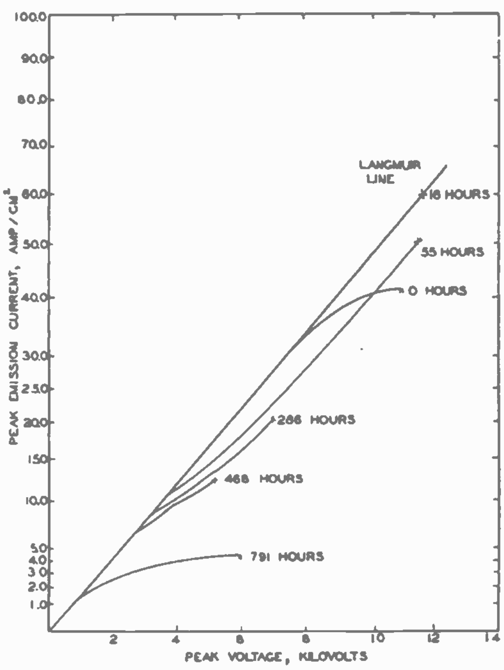

Fig. 4—Pulsed current-versus-voltage characteristics plotted on two-thirds-power scale. The curves obtained at various stages during the life of the cathode are all carried to sparking.

under laboratory conditions. Space-charge-limited emissions of 50 amperes per square centimeter have been consistently obtained when the procedures are carefully controlled. The maximum emission attainable is limited by the occurrence of sparking, a phenomenon which will be discussed in detail in a subsequent section.

Several prime types of current-versus-voltage characteristics are observed:

(1) Space-charge-limited emission, up to the point at which sparking imposes the ultimate limitation (see Fig. 6);

(2) Normal Schottky effect, in which the experimental points follow the Schottky equation after departure from space-charge limitation (see Fig. 4);

(3) Anomalous Schottky effect, in which the $I^{2/3}$ versus V curve has an inflection point in the Schottky region (see Fig. 4).

Among other forms of pulsed characteristics which have been observed is that in which the slope in the Schottky region is zero. In this case the emission curve may follow the space-charge line in the normal manner, and then show an almost complete saturation. It is evident that the presence of gas would be evidenced by large and random fluctuations in the experimental curves or by systematic departures above the space-charge line. Characteristics of type (1) are very difficult to obtain in magnetrons, but are observed in carefully prepared test diodes.

Several useful parameters have been selected for attempts at correlations between oscillating and diode measurements in magnetrons. These will not be considered in detail, although one example will be presented in a subsequent section.

V. Sparking of Magnetron Cathodes

An important limitation to the ultimate performance available with magnetrons is imposed by the phenomenon of sparking. The term *spark*, as used in this connection, designates an explosive discharge precipitated by gas or vapor released from cathode or anode. During a spark the electrical resistance of the tube drops practically to zero, and a very bright spot appears on the cathode. In the case of conventional oxide-coated cathodes, small bits of coating material may be expelled from the cathode surface, and sparking may produce a very deleterious effect.

W. E. Ramsey[8] has conducted an extensive series of investigations into this general problem and has correlated his own and other results to provide an adequate account of various mechanisms which may be responsible for sparking phenomena. Several independent triggering devices may be involved, although the subsequent development of a spark is independent of the origin. A cathode spark denotes one initiated at the cathode, whereas an anode spark has a similar origin at the anode. Only the two recognized types of cathode-initiated sparks will be considered here, although it must be emphasized that all potential processes complete, and, particularly when the pulse length exceeds the microsecond range, the anode effects may predominate. Cathode sparking, generally more important with microsecond pulses, appears when either (1) the current density from any point of the cathode exceeds a certain critical value; *or* (2) the field at any point of the cathode surface exceeds a certain critical value. The critical values involved here vary with tube parameters and with time.

Several experiments have established that the trigger mechanism of sparking may lie totally within the cathode. It has been observed[8] that the space-charge-limited sparking current varies as a function of cathode temperature, as is shown in Fig. 5. Inasmuch as all of the sparks in this instance occurred with the field at the surface of the cathode equal to zero, these sparks are not field-dependent, but are of type (1).

Fig. 6. contains the results of an interesting phenomenon discovered in a related series of experiments,[8]

[8] W. E. Ramsey, W. E. Danforth, and M. A. Pomerantz, "Sparking phenomena in high vacuum thermionic vacuum tubes," *Jour. Frank. Inst.* (to be published).

the increase in the critical sparking current as a consequence of simultaneously drawing a direct current during pulsed measurements. The circuit arrangement for

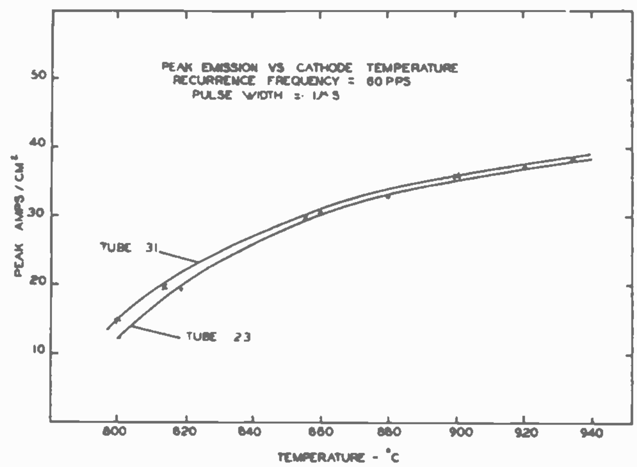

Fig. 5—Curves showing effect of cathode temperature (hence cathode resistance) upon maximum sparking-limited emission.

these experiments is shown in Fig. 3. It is seen that the emission at a cathode temperature of 850 degrees centigrade runs space-charge-limited to above 150 amperes per square centimeter and that sparking has been advanced from about 45 amperes per square centimeter

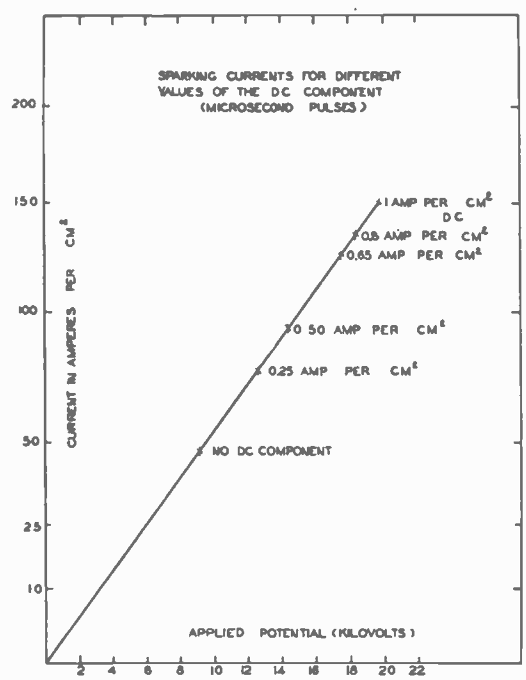

Fig. 6—Curve demonstrating the increase in space-charge-limited emission at sparking, produced by simultaneously drawing direct-current emission during the measurements.

with no direct current to the aforementioned spectacularly high value with a direct-current component of 1 ampere per square centimeter.

Experiments described in the following section concerning cathode-coating resistance have indicated (a) that the effect of the direct current is to diminish the resistance of the cathode, and (b) that the cathode resistance decreases as the temperature is raised. The aforementioned results are consistent with the hypothesis that a cathode spark follows a burst of gas or vapor produced by a dielectric breakdown in the cathode coating or interface arising from the presence of a field due to the IR drop. These fields are actually of sufficient magnitude to produce such an effect. Danforth[4] has found that the internal cathode field at which sparking occurs remains relatively constant as other parameters are varied.

The existence of sparking of type (2) has been established by the Radiation Laboratory Cathode Research Group[5] and by Ramsey, in experiments employing special techniques, as well as by Danforth in earlier work. This type of sparking by definition occurs only in the emission-limited state. Conditions for its occurrence must be such that the critical field is attained without exceeding the critical sparking current (type (1)) for the temperature involved. In practice, field sparking occurs late in the life of an oxide-coated cathode, but may occur at any time with cathodes of poor emitting capacity, as Ramsey has demonstrated. Fields of the order of magnitude of 100,000 volts per centimeter generally produce the effect, which is independent of temperature over a considerable range.

Even with microsecond pulses, under certain conditions encountered in actual magnetron operation, the types of sparking attributable to the anode may predominate. The exceedingly high values of radio-frequency fields which may be attained create a complicated situation, as does the concentration during oscillations of extremely intense localized bombardment on regions which are not accessible for degassing during tube processing.

VI. Cathode Resistance and Pulse Temperature Rise

A cathode in a diode undergoing no back-bombardment manifests a temperature increase when high pulsed currents are emitted. This increase in temperature depends upon the peak current, the duty cycle, and the state of the cathode. Presumably, the pulse temperature rise is attributable to the I^2R dissipation within the cathode during the flow of the peak current I. The average power dissipated within the cathode in this manner is represented by the expression

$$P = I^2 R \nu \tau \tag{1}$$

where ν is the repetition frequency and τ is the pulse width. Of course, the cooling due to the emission $I\phi\nu\tau$ must be subtracted from this value. The net temperature rise may amount to almost 200 degrees centigrade at peak emission currents of 30 amperes per square centimeter with one-microsecond pulses occurring at the rate of 1000 per second. Values of R may vary within the range 1 to 100 ohm-centimeters squared. Danforth[4] has investigated the dependence of cathode resistance upon various conditions by a method involving the

[4] W. E. Danforth, "Cathode coating resistance as measured by embedded probes," to be published.

[5] E. A. Coomes, J. G. Buck, A. S. Eisenstein, and A. Fineman, "Cathodes for pulsed magnetrons, Part II," National Defense Research Council Report 14-683, January 31, 1945.

measurement of potentials of probes embedded within the coating. The results may be summarized as follows:

(a) The absolute values of resistance are in the same range as those obtained by a calorimetric technique at the Radiation Laboratory.[5]

(b) The resistance versus pulsed-current curves at different temperatures show maxima.

(c) A suggestive correlation can be drawn between resistance and sparking current, especially when comparing the behavior of BaO-coated cathodes with SrO-coated cathodes.

(d) The absolute magnitude of probe voltage at sparking is consistent with the dielectric-breakdown hypothesis of cathode-initiated sparking.

(e) The variation of resistance with temperature depends upon temperature in the manner previously observed by others.

A typical set of data are presented in Fig. 7. In this instance the coating resistance is negligible compared with that appearing at the interface between the coating and the nickel sleeve.

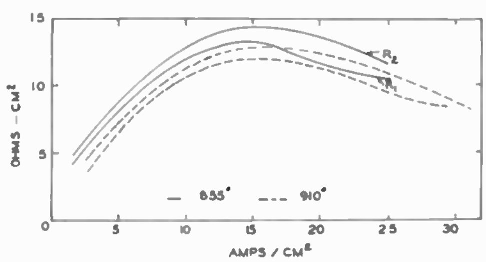

Fig. 7—Cathode resistance versus peak emission current at two temperatures, as measured between the nickel sleeve and two probes embedded at different levels in the coating. In this instance, the coating resistance is negligible compared with that of the interface between coating and base metal (R_1 and R_2 are practically equal).

VII. Secondary Electron Emission—Cold Cathodes

Because of the importance of secondary electron emission in the operation of the magnetron, an extensive series of investigations has been performed in this field.[6] Various factors affecting the yield (δ = number of secondary electrons emitted per incident primary electron) such as the dependence upon primary voltage, cathode temperature, etc., have been studied. Special tubes, designated SE tubes, have been utilized for measuring the secondary-emission characteristics of various types of magnetron cathodes. 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. Fig. 8 contains typical curves obtained at various cathode temperatures. It has been observed that the yield increases with temperature in an exponential manner, confirming earlier results of Morgulis and Nagorsky[7] on oxide-coated cathodes. Our results have disclosed that the yields may exceed 100 at 850 degrees centigrade for laboratory-processed cathodes. Furthermore, it has been demonstrated that the secondary emission depends upon the degree of activation and increases with enhance-

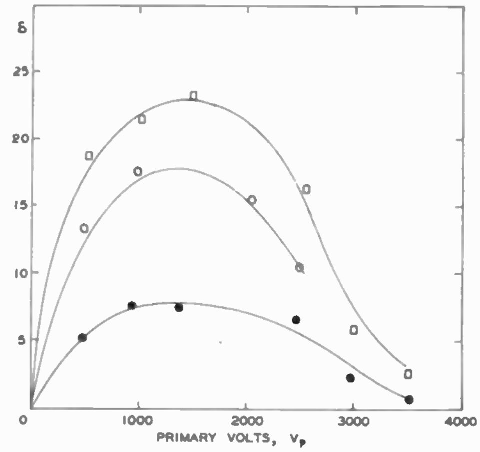

Fig. 8—Secondary electron yield δ versus primary energy at different cathode temperatures.
● = Room temperature
○ = 615 degrees centigrade
□ = 660 degrees centigrade

ment of the thermionic emissivity. However, even extremely poor cathodes inferior to production standards probably have yields exceeding 10.

Short-time effects, such as growth or decay of secondary current after the onset of primary bombardment or persistence after the cessation of bombardment, have not been observed by us, and values of yield obtained by pulsed methods are in accord with those obtained under direct-current conditions.

Various investigators, originally including Oliphant in England and later McNall,[8] have operated magnetrons solely by secondary electron emission. Fig. 9 indicates several alternative arrangements for accomplishing this. In all cases, it is necessary to provide an auxiliary source of primary electrons for initiating the oscillations. This has generally been referred to as the auxiliary emitter or pilot electrode. It has been established that pilot currents amounting to only a small fraction of the

(a) (b) (c)

Fig. 9—Cold-cathode types utilized in magnetrons operated primarily by secondary emission.
(a) An oxide coating is applied to a hat, which is heated by a filament wire as indicated.
(b) A loop of tungsten wire, which functions as the pilot emitter, is utilized.
(c) A pilot cathode is adjacent to the surface of the secondary emitting cathode.

anode current in the oscillating state suffice. We have utilized the cathode illustrated in Fig. 9(c) using an ordinary oxide-coated cathode as the secondary emitting electrode. Emissions of milliamperes from the pilot

[6] M. A. Pomerantz, "Secondary electron emission from oxide-coated cathodes," *Phys. Rev.*, vol. 70; July, 1946; *Jour. Frank. Inst.*, vol. 241, pp. 415–433; June, 1946; vol. 242, pp. 41–61; July, 1946.

[7] N. Morgulis and A. Nagorsky, "Secondary electron emission from oxide-coated cathodes," *Tech. Phys. U.S.S.R.*, vol. 5, pp. 848–863; December, 1938.

[8] J. W. McNall, "An investigation of peak electron emissions from various cathode materials," thesis, Massachusetts Institute of Technology, May 18, 1942.

permitted the attainment of anode currents of 10 amperes in the tube type studied. Similar results have been obtained using other secondary-emission cathodes, such as silver-magnesium alloy, oxidized nickel, etc. However, cold cathodes have not yet been adapted to production tubes.

VIII. Back-Bombardment in Magnetron Cathodes

As has been previously stated, in operation a fraction of the electrons which leave the cathode may return with a finite velocity, thereby increasing the cathode temperature. This may result in the attainment of excessively high cathode temperatures. Back-bombardment in magnetrons has been studied by Balls and Megaw in England, and by Danforth.[9] Under actual operating conditions, cathode-temperature rises of hundreds of degrees may occur. Experimental results have established that the back-bombardment power may range from 3 to 20 per cent of the output power under various extreme conditions of operation. Both the loading and the locus of the operating point on the performance chart affect this quantity. By an analysis which utilized experimental measurements of the secondary yield from oxide cathodes (see preceding section) and the number and energy of back-bombarding electrons, Danforth was able to compute the yield with which a particular 10-centimeter-band magnetron can operate by secondary emission alone at various points on the performance chart.

IX. Correlation Between Magnetron Performance and Thermionic Emission

Various attempts to correlate thermionic emission characteristics with magnetron performance have been made. It has been observed particularly by the Cathode Research Group of the Radiation Laboratory[10] that prominent limitations in magnetron performance appear to depend upon the cathode even after geometrical design problems on a tube have been completed. These limitations occur as instabilities in performance, generally classified into two types: (a) sparking, and (b) other flicker effects which are a certain type of frequency instability and of which moding and poor spectrum are the most apparent. Steps were taken toward determining the correlations between the performance phenomena and cathode quality as determined from the diode characteristics of magnetrons. However, several factors render it extremely difficult to attain such correlations, perhaps the most important being that it has been necessary to compare data obtained with a number of different tubes in which slight geometrical differences could of course be extremely important.

Only one such correlation will be considered here for illustrative purposes. J. G. Buck[10] originally concluded from data obtained with a number of tubes that the high-current-mode boundary and other types of flicker in a magnetron are dependent upon the primary emission available from a cathode at the time oscillation starts near the beginning of the pulse. Utilizing a new type of thoria cathode,[11] it has been possible recently to obtain a complete set of such data with a single tube. An essential feature of this cathode is that the thermionic emission can be controlled over wide limits merely by varying the temperature, an advantage which is rendered possible by the stability of the emission characteristics. The observation made at the Radiation Laboratory that there is good evidence for the existence of a minimum of primary emission below which stable operation cannot be expected at the selected operating point has been very unambiguously confirmed, as is seen in Fig. 10. It has also been verified that the minimum thermionic emission necessary for a given anode current in the oscillating state depends markedly upon pulse shape; hence, the characteristics of the modulator, pulse transformer, or any despiking network utilized are determining factors.

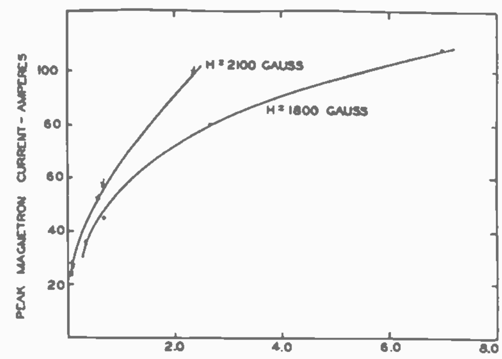

Fig. 10—Curves of maximum magnetron current before moding versus maximum space-charge-limited emission (MSCLE), obtained with a single tube containing thoria cathode. Type 4J32 (HK7). Test conditions: 400 pulses per second, 0.9 microsecond.

The maximum space-charge-limited emission was varied by changing the cathode-heater power. The precise shape of the curve is modified somewhat by back-bombardment, but the correction is relatively small because back-bombardment power is low compared with heater power.

It should be noted that the maximum space-charge-limited emission is considerably lower than the peak oscillating currents.

Apropos of the topic with which this section has been concerned, the problem of hat emission should be cited. Under certain circumstances, emission from the uncoated portions of the cathode structure may adversely affect the operation of the magnetron, introducing losses, certain types of instability, and other peculiarities of behavior. In analogy with ordinary grid emission, the difficulty arises as a consequence of the evaporation of coating material onto the hats, which may attain emitting temperature. Furthermore, the hats may be subjected to back-bombardment during oscillations. The situation has been alleviated by coating the susceptible members with poisoning agents capable of inhibiting emission.

[9] W. E. Danforth, C. D. Prater, and D. L. Goldwater, "Back-bombardment of magnetron cathodes," National Defense Research Committee Report 14-309, August 25, 1944.

[10] E. A. Coomes, J. G. Buck, and A. Fineman, "Cathodes for pulsed magnetrons, Part I," National Defense Research Committee Report 14-609, August 30, 1944.

[11] M. A. Pomerantz, "The sinthor cathode—a new electron-emitting structure," *Jour. Appl. Phys.* (to be published).

X. Life of Magnetron Cathodes

Owing to the extremely drastic conditions to which magnetrons are subjected in operation, the useful life is considerably shorter than in the case of cathodes in standard radio tubes. Considerable effort has been concentrated upon extending the life which, in some cases, may be too short for dependable service in practical applications. Certain magnetrons may survive only 50 hours or less. Even the most widely used and well-developed types are rated at less than 1000 hours, which falls far short of the life of 10,000 or 20,000 hours sometimes realized with commercial tubes. The short life spans of cathodes in magnetrons is understandable from a consideration of the requirements summarized in the following section.

A typical life history of an oxide-coated cathode operating under pulsed conditions in a diode is seen in Fig. 4. It is significant that no unambiguous correlations between pulsed and direct-current properties exist. Whereas it might be stated that efficient pulsed emitters are also good direct-current cathodes, the converse is not necessarily true. For example, good oxide cathodes operating at 400 milliamperes per square centimeter direct current have shown a tendency to gain during the first 500 hours of life, while the pulsed emission slumped steadily from an initial value of about 50 to less than 20 amperes per square centimeter at the end of this period.[10]

XI. Requirements of Magnetron Cathodes

Having discussed the various conditions encountered by magnetron cathodes, it is now possible to summarize those features which are essential for successful use:

(1) Ability to provide high electron-emission densities either by thermionic emission, by secondary emission, or by a combination of both processes, for long periods of time.

(2) Satisfactory sparking properties: i.e., freedom from sparking under standard operating conditions.

(3) The ability to withstand violent punishment accorded by sparking, bombardment, and other destructive phenomena.

(4) Relative stability.

(5) The ability to operate at temperatures higher than the rated operating temperature, and to dissipate high back-bombardment power.

(6) Freedom from decay, particularly in cases where it is desired to extend the pulse length.

As a rough estimate, it may be stated that a cathode designed for a 3-centimeter-band magnetron should be capable of supplying about 30 amperes per square centimeter peak space-charge-limited current for duty cycles as high as a few tenths of one per cent; for 10-centimeter-band magnetrons the figure for current density may be lowered to about 10 amperes per square centimeter, while this figure must be increased to about 90 for magnetrons operating in the 1-centimeter band.

Not all of the above requirements have thus far been satisfied, either with the various standard types of cathode or with ingenious modifications thereof. Three forms of coated cathodes have been utilized most extensively thus far. The plain, uncombined oxide-coated cathode consists of a carefully prepared nickel sleeve coated with a mixture of alkaline earth carbonates in a binder, and processed in a prescribed manner. Improvement in stability and life has been attained by use of the screen cathode, constructed by applying an uncombined carbonate coating to a nickel mesh in intimate contact with the cathode sleeve. The metallized cathode developed by Moore contains fine nickel powder initially added to the uncombined coating. Fig. 11 illustrates several typical magnetron cathodes.

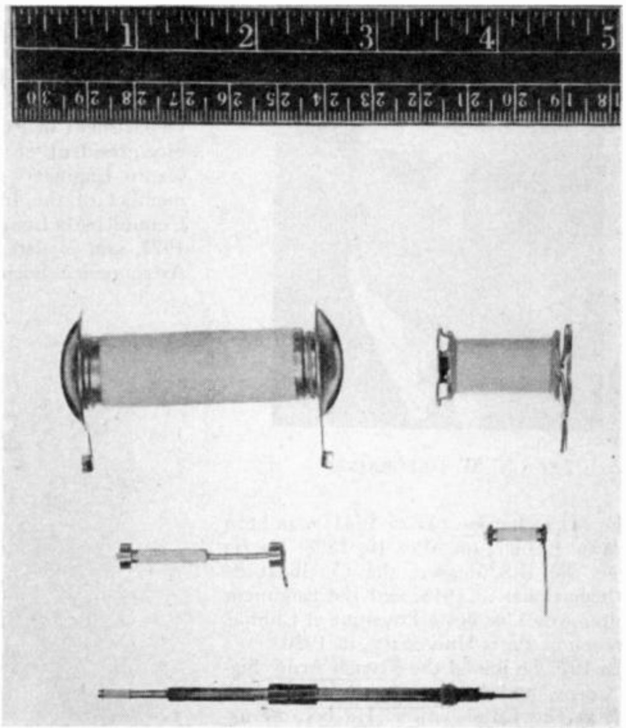

Fig. 11—Representative magnetron cathodes, including screen and ordinary varieties.

Some attempts have been made to utilize tungsten, thoriated-tungsten, or other filamentary cathodes wound in helical form, but these possess obvious disadvantages. Japanese radar was seriously handicapped as a consequence of their choice of tungsten filaments, probably dictated by difficulties encountered in the production of satisfactory oxide-coated cathodes. The cathode situation is particularly serious for continuous-wave magnetrons, or even for tubes operating on longer pulse lengths.

In view of the aforementioned considerations, effort has been directed toward the development of a cathode[11] differing radically from existing types. The resulting new type of cathode, which appears satisfactorily to fulfill all of the aforementioned requirements, comprises essentially a self-supporting fired or sintered body of thorium oxide heated in any one of various manners. It has been designated as the "sinthor" cathode, and promises to find wide applications both in magnetrons and in other tube types.

XII. Acknowledgements

Various individuals have been instrumental in arriving at many of the conclusions presented in this paper. The Cathode Research Group of the Radiation Laboratory, Massachusetts Institute of Technology, has been responsible for a number of the procedures and ideas embodied herein; and credit for much significant work on this subject should be accorded E. A. Coomes, J. G. Buck, A. E. Eisenstein, and A. Fineman. Finally, it is a pleasure to acknowledge the contributions to this field of research made by the author's colleagues at the Bartol Research Foundation, particularly W. E. Danforth, W. E. Ramsey, C. D. Prater, and D. L. Goldwater.

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MARTIN A. POMERANTZ

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For biography and photograph of H. C. Early, see the October issue of the PROCEEDINGS OF THE I.R.E. AND WAVES AND ELECTRONS

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Abstracts and References

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ACOUSTICS AND AUDIO FREQUENCIES

534.131 **2791**

Reflection and Refraction of Non-Stationary Elastic Waves—Gogoladze. (*See* 2862 and 2864.)

534.131 **2792**

On Rayleigh Boundary Waves—Gogoladze. (*See* 2863.)

534.231 **2793**

The Sound Field of Moving Sound Sources—M. F. Shirokov. (*Compt. Rend. Acad. Sci.* (U.R.S.S.), vol. 49, pp. 494–496; December 10, 1945. In English.) An attempt to find "a new solution of the differential equations of acoustics with sources moving in the medium."

534.321.9 **2794**

On Method in Supersonic Absorption Measurements—E. J. Pumper. (*Compt. Rend. Acad. Sci.* (U.R.S.S.), vol. 49, pp. 558–560; December 20, 1945. In English.) A new method of measurement is described in which an acoustic tone-modulated transmitter of supersonic radiation (quartz crystal) is used with a microphone membrane as receiver. The microphone output contains a modulation-frequency component, of amplitude proportional to the square of the intensity of the incident supersonic wave, which gives a measure of the absorption in the liquid or gas interposed between transmitter and receiver.

534.43:621.395.61 2795

Improved Modulated-Oscillator [Gramophone] Pickup—H. Kalmus. (*Electronics*, vol. 19, pp. 182–186; July, 1946.) Improved version of the pickup circuit described in 1154 of May (Kalmus). Audio output is increased by 15 to 20 decibels, noise is reduced in the same ratio, and microphonics are reduced by 6 decibels.

534.43:621.395.61:621.396.619.018.41 **2796**

Simplified Frequency Modulation [Applied to Gramophone Pickup]—Bruck. (*See* 2853.)

534.7:621.395.645 **2797**

Auditory Perception—J. D. Goodell and B. M. H. Michel. (*Electronics*, vol. 19, pp. 142–148; July, 1946.) An inverse volume-expansion circuit for automatic tone control is described. It compensates for changes in the response of the ear at different intensity levels. Factors affecting the design and use of various audio-frequency connecting circuits are discussed in relation to the subjective effect of the results.

534.76 **2798**

The Formation of Stereophonic Images—K. de Boer. (*Philips Tech. Rev.*, vol. 8, pp. 51–56; February, 1946.) General discussion, with particular reference to the conditions under which sound must be recorded for stereophonic effects.

534.862+621.397 **2799**

S.M.P.E. [Society of Motion Picture Engineers] Spring Technical Conference [New York, N. Y., May, 1946].—(*See* 3087.)

621.317.79:621.395.82:621.395.645 2800

Intermodulation Testing [of Audio-Frequency Amplifiers]—Hilliard. (*See* 2978.)

621.395.613.32 **2801**

Microphones: Part 4—S. W. Amos and F. C. Brooker. (*Electronic Eng.*, vol. 18, pp. 255–258; August, 1946.) An account of the theory and construction of the ribbon velocity-type microphone and of its performance compared with other types. Polar diagrams and response curves are given. Special British Broadcasting Corporation—Marconi velocity types and combined pressure and velocity microphones are also described in detail. Conclusion of series; for previous parts, see 2458 of September and back references.

621.395.623.8 **2802**

Beachmaster Announcing Equipment—L. Vieth. (*Bell Lab. Rec.*, vol. 24, pp. 261–263; July, 1946.) A general account. See also 532 of March (Duffield).

621.395.625 **2803**

Recording and Broadcasting of Preparations for Bikini Atom-Bomb Test—A. A. Kees. (*Communications*, vol. 26, pp. 11–13; July, 1946.) Outline of methods used to overcome technical difficulties of sound recording in aircraft and under difficult climatic conditions.

621.395.625.3 **2804**

Signal and Noise Levels in Magnetic Tape Recording—D. E. Wooldridge. (*Trans. A.I.E.E.* (*Elec. Eng.* June, 1946), vol. 65, pp. 343–352; June, 1946.) Statistical variations in net flux entering the pole pieces, due to finite size of magnetic domains in the tape material, is the only source of noise completely explainable. Detailed consideration is given to hysteresis processes in the erase-record-reproduce cycle. The magnitude of overload signal is predicted in terms of the coercive force of the tape material and the reluctance of the magnetic circuit. A combination of a new vicalloy tape, the superposed high-frequency method of recording, and a new unit design results in high quality recording from 100 to 8000 cycles with a useful volume range of more than 50 decibels.

621.395.625.6 **2805**

Preliminary Sound Recording Tests with Variable-Area Dye Tracks—R. O. Drew and S. W. Johnson. (*Jour. Soc. Mot. Pic. Eng.*, vol. 46, pp. 387–404; May, 1946.) Measurements on frequency response, noise, and distortion, with photocells having various spectral response curves.

621.395.625.6:621.383 **2806**

Behavior of a New Blue-Sensitive Phototube [for Black-and-White or Colour Film Tracks] in Theater Sound Equipment—J. D. Phyfe. (*Jour. Soc. Mot. Pic. Eng.*, vol. 46, pp. 405–408; May, 1946.)

621.395.625.6:621.383 **2807**

A Phototube for Dye Image [Colour Film] Sound Track—Glover and Moore. (*See* 3076.)

AERIALS AND TRANSMISSION LINES

621.315.1.056.1 **2808**

Tension in Hanging Wires—G. Hookham. (*Engineering*, (London), vol. 161, p. 460; May 17, 1946.) Geometrical construction for tensions at the ends of fairly taut wires with known sag.

621.315.21.029.5/.6 2809
Design Data and Characteristics of High-Frequency Cables: Parts 1 and 2—K. Zimmermann. (*Radio*, vol. 30, pp. 13–15 and 20–34; May and June, 1946.) Cables for centimeter wavelengths require rigid mechanical and electrical specifications. Design data for obtaining a suitable characteristic impedance and attenuation with the required strength and flexibility are given for the following types: (1) coaxial cable with stranded inner conductor and low-loss dielectric; (2) coaxial cable, air-spaced by means of a spiral of polythene; (3) high-impedance cable having a spiral inner conductor; (4) dual coaxial for a high degree of balance; (5) screened twin cable; and (6) twin unscreened. The second part discusses causes of attenuation, the power rating, and typical design problems.

621.315.21.029.6:621.317.3 2810
Measurement of Velocity of Propagation in Cable—Kramer and Stolte. (*See* 2977.)

621.315.212.1.017 2811
Current Rating of Single-Core Paper-Insulated Power Cables—C. C. Barnes. (*Elec. Commun.*, vol. 23, pp. 70–95; March, 1946.) An outline of a method for computing the ratings. The effect of sheath losses, skin effect, proximity effect, and dielectric loss are discussed in detail. Current rating for special cases of cables in water, air, and ducts, and for particular types of cables are calculated and tabulated.

621.315.221:669.45 2812
[Chemical] Analysis of Cable Sheathing Alloys—Hamilton. (*See* 2947.)

621.315.229 2813
Jacketing Materials for High-Frequency Transmission Lines—Warner. (*See* 2929.)

621.319.7:621.392 2814
Some Applications of Field Plotting—E. O. Willoughby. (*Jour. I.E.E.* (London), part III, vol. 93, pp. 275–293; July, 1946.) "By the process of field-plotting in the cross-section of a uniform transmission line, an orthogonal field pattern of curvilinear squares satisfying the boundary conditions is obtained. If N_e is a number of voltage steps and N_f the number of electrostatic flux lines in this field plot, the characteristic impedance is given by

$$Z=377(N_e/N_f)\sqrt{\mu/\kappa}$$

where μ is the permeability, and κ is the permittivity.

"Application to coupling and screening are also considered.

"The use of models in an electrolytic tank for capacitance determination from field plots or direct measurement is discussed, and an axially symmetrical three-dimensional field is plotted. Mention is made of the relaxation process and rubber-sheet methods of field-plotting."

621.392+621.316.35.011.3 2815
Formulas for the Inductance of Coaxial Busses Comprised of Square Tubular Conductors—H. P. Messinger and T. J. Higgins. (*Trans. A.I.E.E.* (*Elec. Eng.*, June, 1946), vol. 65, pp. 328–336; June, 1946.)

621.392+621.396.11 2816
Propagation of Electromagnetic Waves Along a Single Wire—Vladimirski. (*See* 3008.)

621.392 2817
Characteristic Impedance of Balanced Lines—P. J. Sutro (*Electronics*, vol. 19, p. 150; July, 1946.) Three equations for the Z_0 of a balanced two-wire transmission line with cylindrical shield are compared, and expressions given for the errors in each equation.

621.392 2818
Anomalous Attenuation in Waveguides—J. Kemp. (*Wireless Eng.*, vol. 23, pp. 211–216; August, 1946.) "The puzzling phenomenon of decreasing attenuation constant with increasing frequency, which occurs in a few isolated instances, is here elucidated by treating the guides concerned as limiting cases of a guide of more general shape, in the interior of which the waves display the normal properties characteristic of waves in guides generally. The equations of the electromagnetic field, cut-off frequency, and attenuation constant describing the isolated cases are then, in like manner, deduced as limiting cases from those appropriate to a guide of general shape. The isolated cases thus lose their character of isolation and assume that of straightforward limits instead. According to the point of view developed in the paper, these limiting cases imply an electromagnetic field which extends to infinity along one of the transverse coordinates but, being wrapped around the axis of the guide, the field is constrained to exist in finite space where it continues to display the properties characteristic of a field of infinite extent."

621.392:621.396.67 2819
Aerial-to-Line Couplings—Burgess. (*See* 2835.)

621.392.43 2820
Transmission Lines as Impedance Transformers—L. R. Quarles. (*Communications*, vol. 26, pp. 20–38; July, 1946.) The solution of typical problems involving the quarter-wave line and open- and shorted-stubmatching. The use of the circle diagram is explained. The last of a series; for previous parts see 2478 and 2480 of September.

621.396.67 2821
Aerials—"Cathode Ray" (*Wireless World*, vol. 52, pp. 223–225; July, 1946.) Elementary theory of radiation from current elements.

621.396.67 2822
The Radiation Field of an Unbalanced Dipole—W. Kelvin. (Proc. I.R.E. and Waves and Electrons, vol. 34, pp. 440–444; July, 1946.) A method for obtaining the magnitude of the electric field in the distant zone of a symmetrical dipole with unequal branch currents is described. The result involves two functions of the vertical angle, plots of which are given for four values of h, the half-length of the dipole. Curves of the distant-zone electric field are given for values of h and of k, the ratio of the branch currents at the driving points. Experimental field patterns are plotted for several dipole lengths.

621.396.67 2823
Slotted Tubular Antenna for 88 to 108 Mc—C. R. Jones. (*Communications*, vol. 26, pp. 36–39; July, 1946.) Short technical description of an aerial design by A. Alford for horizontal polarization.

621.396.67 2824
The New Antenna Types and Their Applications—A. G. Kandoian. (*Elec. Commun.*, vol. 23, pp. 27–34; March, 1946.) Reprint of 1180 of May.

621.396.67:538.56 2825
On the Excitation of Vibrators in Antennae—M. A. Leontovich and M. L. Levin. (*Bull. Acad. Sci.* (U.R.S.S.), sér. phys., vol. 8, no. 3, pp. 156–163; 1944. In Russian.) Complete paper of which an English summary was abstracted in 2618 of 1945.

621.396.67:621.397.6 2826
CBS Tele Antenna—O. J. Sather. (*Elec. Ind.*, vol. 5, pp. 68–69; July, 1946.) Design and constructional details of a folded dipole video radiator for operation at 51.25 megacycles. A heater is provided for removing ice.

621.396.677 2827
An Inexpensive 3-Element [Rotating] Beam [Antenna] for 28 Mc—C. E. Nichols. (*QST*, vol. 30, pp. 27–31, 126; August, 1946.) Constructional details.

CIRCUITS

621.3.011.2 2828
Impedance Calculations—H. Horwood. (*Elec. Rev.*, (London), vol. 138, pp. 846–847; May 31, 1946.) Graphical method for impedances in parallel.

621.3.012.3 2829
System of Graphing Capacities and Inductances—A. S. Runciman. (*Elec. Eng.*, vol. 65, p. 300; June, 1946.)

621.3.012.3 2830
Nomograph Construction: Part 1, Nomograph for Current, Voltage and Resistance—F. Shunaman. (*Radio Craft*, vol. 17, pp. 609, 633; June, 1946.)

621.314.2.029.5:621.396.619.018.41 2831
The Theory and Design of Intermediate-Frequency Transformers for Frequency-Modulated Signals—H. A. Ross. (*A.W.A. Tech. Rev.*, vol. 6, pp. 447–471; March, 1946.) The design criteria are shown to be (a) the amount of amplitude modulation introduced into the frequency-modulation signal by the selective circuits, and (b) the linearity of the phase-angle versus frequency characteristic of the secondary current. Maximum linearity is obtained when the transformers are critically coupled. The characteristic remains almost linear with a small degree of over-coupling, and the design of over-coupled transformers is discussed. Design charts are given for critically coupled transformers. The power relations

in a frequency modulated signal which has been subjected to transmission through selective circuits are also discussed.

621.316.578.1 **2832**

One Tube—One Relay Multi-Time Circuits—V. Wouk. (*Elec. Ind.*, vol. 5, pp. 48–52, 98; July, 1946.) A single thyratron is used to perform multiple timing operations by the addition of resistance-capacitance combinations to the grid and anode circuits. A typical single or repeating two-interval timer provides interval ranges from 0.05 second to 3 minutes and 0.07 second to 10 seconds. Details are given of multiple-interval timers.

621.385:621.396.822 **2833**

Fluctuations in Electrometer Triode Circuits—A van der Ziel. (*Physica*, (Eindhoven), vol. 9, pp. 177–192; February 1942. In English.) "The influence of fluctuations on the accuracy of measurement of small currents by an electrometer triode is investigated theoretically and the results compared with earlier theoretical and experimental work. Only two sources of fluctuations are important, thermal noise in the input circuit, and the shot effect of the grid current. The mean-square error is calculated for three methods of measurement: first, when the final deflection of the galvanometer in the anode circuit is read once, second, when the deflection is averaged over a long time, and third, when the input circuit resistance R_g is usually high ($10^{14}\Omega$) and the increase of deflection in a given time is observed. It is found that in the latter case the [root]-mean-square error is only about 2.10^{-18} amperes."

621.392 **2834**

On Approximate Integration of van der Pol's Equation—V. V. Kazakevich. (*Compt. Rend. Acad. Sci.* (U.R.S.S.), vol. 49, pp. 414–417; November 30, 1945. In English.) Mathematical note on a method of approximate investigation of nonlinear systems. The method enables the process of establishment, the form, and the period, to be determined, and "is easy to modify for application to nonoscillatory systems."

621.392:621.396.67 **2835**

Aerial-to-Line Couplings—R. E. Burgess. (*Wireless Eng.*, vol. 23, pp. 217–221; August, 1946.) "In the present paper two systems are considered:—(a) the constant-resistance network, and (b) the cathode follower. The overall loss in signal/noise ratio for these systems is compared with that which occurs for direct connection of the aerial to the line. The loss which occurs at the receiving end of the line is likely to be smaller and more constant with coupling networks at the sending end which match to the line than for direct connection.

"Criteria are derived to show in what conditions each of the systems is preferable and these are expressed in terms of the line attenuation αl and the ratio of the aerial reactance to the characteristic impedance of the line; i.e., $|X|/R_0$. It is found that when $|X|/R_0$ is less than about unity, direct connection is best unless the line attenuation is very large, in which case the constant-resistance network may have an advantage. If $|X|/R_0$ is greater than about 3, the cathode follower is generally best, its superiority being the greater the larger the line attenuation. The conclusions of the analysis are considered to be valid for frequencies up to about 30 megacycles, assuming the aerial to be substantially reactive over the range concerned.

"A numerical example for a typical case of a capacitive aerial operating over a wide range of frequency is given."

621.392.41.015.3:517.512.4 **2836**

On Transients in Homogeneous Ladder Networks of Finite Length—W. Nijenhuis. (*Physica*, (Eindhoven), vol. 9, pp. 817–831; September, 1942. In English.) The problem considered is that of the voltage and current distribution in a finite homogeneous ladder network of n T-sections with lumped constants, resulting from the application of an impulse voltage at the input end, the network being short circuited at the other end. It is shown that solutions may be obtained in two different forms, closely analogous to the two solutions for the vibration of a stretched string, due respectively to d'Alembert and Euler and to Bernoulli. A brief historical account is given of the stretched-string problem, and the electrical problem is then solved in general terms by the use of the Laplace transformation.

The case of a low-pass filter is discussed in detail and the solution developed in its two forms, one consisting of a series of Bessel functions and corresponding to the d'Alembert-Euler solution, and the other a series of sine or cosine terms corresponding to the Bernoulli form. Comparison of these two forms gives an approximate Bessel function expansion in terms of a sine and cosine series. The approximation becomes progressively closer as the number of sections in the filter is increased.

A second case considered is that of a resistance-capacitance ladder network for which the same differential equation applies as for the problem of diffusion. In this case equating the alternative forms of solution gives an expansion for Bessel functions with imaginary argument in terms of a sine and cosine series.

621.392.43 **2837**

Graphical Solution of Matching Problems—G. Glinski. (*Elec. Ind.*, vol. 5, pp. 64–65; August, 1946.) Description of a simple design method, using circle diagrams, for matching with L, T, or π networks.

621.392.43 **2838**

Transmission Lines as Impedance Transformers—Quarles. (*See* 2820.)

621.392.5 **2839**

Differentiating Circuit—(*Wireless World*, vol. 52, pp. 231–232; July, 1946.) Determination of suitable component values for a differentiating circuit with an exponential input-voltage waveform. Curves are given showing output waveform as a function of component values. See also 3843 of 1945 (Ohman).

621.392.52 **2840**

Theory and Application of Parallel-T Resistance-Capacitance Frequency-Selective Networks—L. Stanton (PROC. I.R.E. AND WAVES AND ELECTRONS, vol. 34, pp. 447–456; July, 1946.) A general treatment of the network including an account of its advantages and limitations, and dealing with its theory and applications. A single π-circuit is derived by means of star-delta transformations, and expressions are obtained for the network transmission and its phase shift at any frequency. Design considerations such as component tolerances and the effect of loading the network are discussed, and three examples, adjustable for resonant frequency and zero transmission, are given. A single-stage negative-feedback circuit is described to illustrate the application of the network.

621.394.397].645 **2841**

Amplifier-Gain Formulas and Measurements—S. J. Haefner. (PROC. I.R.E. AND WAVES AND ELECTRONS, vol. 34, pp. 500–505; July, 1946.) Precise mathematical meanings are given to the usual definitions of amplifier gain. A practical method for measuring the insertion gain of a voltage amplifier is proposed, and the results on an actual amplifier are compared with those obtained from the usual definitions. It is concluded that "the gain of an amplifier" is meaningless unless the method of measurement is stated, and that the method used should have regard to the actual application of the amplifier.

621.394/.397].645.34 **2842**

Nyquist Diagrams for a Thompson System with Two Degrees of Freedom and Their Physical Interpretation—K. Teodorchik. (*Compt. Rend. Acad. Sci.* (U.R.S.S.), vol. 49, pp. 259–262; November 10, 1945. In English.) A mathematical paper in which Nyquist's stability criterion is considered for linear and nonlinear regeneration circuits. "In a nonlinear system both the amplification coefficient μ and the phase angle ψ are variable not merely with the frequency p, put also with the output amplitude u_0. Therefore, a nonlinear system is characterized by a family of Nyquist diagrams depending on a single parameter u_0 rather than by one diagram." See also 567 of March (Leonhard).

621.394/.397].822+621.392.6 **2843**

Suppression of Spontaneous Fluctuations in Amplifiers and Receivers for Electrical Communication and for Measuring Devices—M. J. O. Strutt and A. van der Ziel. (*Physica*, (Eindhoven), vol. 9, pp. 513–527; June, 1942. In English.) From a general analysis of the signal-to-noise ratio of a linear 4-terminal network with linear feedback it is concluded that the ratio is unaffected by such feedback whether positive or negative. An equivalent circuit is derived for an amplifier with feedback and the optimum signal-to-noise ratio for an amplifier without feedback is calculated. The use of a suitable cathode-lead inductance to produce a "noiseless" input damping resistance for adjustment of bandwidth is described. Means of securing feedback of suitable sign in an amplifier to give a constant input impedance over a given frequency range are mentioned.

The use of a high grid resistance in an electrometer triode with feedback to give the required frequency characteristic enables enhanced accuracy, of measurement to be obtained; similarly, the thermal fluctuations in a galvanometer may be reduced.

The paper was noted in 2088 of 1943.

621.394/.397].822+621.392.6 **2844**

Suppression of Spontaneous Fluctuations in 2*n*-Terminal Amplifiers and Networks—A. van der Ziel and M. J. O. Strutt. (*Physica*, (Eindhoven), vol. 9, pp. 528–538; June, 1942. In English.) This paper extends the earlier work (see 2843 above) on the reduction of fluctuations in amplifiers to the case of 2*n* poles. In Section 2 the application of feedback of either sign on linear 6-poles is considered, and expressions are derived for the noise and signal voltages at the various outputs. Section 3 gives the theorem: the noise-to-signal ratio at every output can be reduced by feedback to the smallest value which exists at any output without feedback. Section 4 is concerned with the effect of various correlations between the fluctuations at the output on the optimum condition obtainable with feedback. In Section 5 examples are given. Section 6 deals with the linear 8-pole and with the application of feedback to reduce the noise-to-signal ratio. Section 7 contains the extension of these results to linear 2*n* poles.

The paper was noted in 2089 of 1943.

621.395.645 **2845**

Three-Channel Amplifier: a 15-Watt Unit with Individual Control of Each Channel—M. Contassot. (*Radio Craft*, vol. 17, pp. 607, 642; June, 1946.)

621.395.645:621.385.5 **2846**

Dynamic Characteristics of Pentodes—S. J. Haefner. (*Communications*, vol. 26, pp. 14–19; July, 1946.) Graphical analysis of their use in designing high-signal-level resistance-coupled amplifiers.

621.396.61 **2847**

Resonant Cavities—L. J. Giacoletto. (*Elec. Ind.*, vol. 5, pp. 60–62; August, 1946.) Curves and data for the design of resonant cylindrical cavities.

621.396.61.029.58 **2848**

Variable Frequency Exciter Unit—G. M. King. (*R.S.G.B. Bull.*, vol. 22, pp. 10–11; July, 1946.) The circuit uses a Franklin type of oscillator tuning over the range 3.5 to 3.8 megacycles, coupled through two buffer stages to an output stage which doubles or trebles the frequency. Frequency stability is comparable with that of a crystal-controlled oscillator.

621.396.611 **2849**

A Mechanical Model Analogous to an Oscillatory Electrical Circuit—Blake. (*See* 3160.)

621.396.615 **2850**

Notes on the Stability of LC Oscillators—N. Lea. (*Jour. I.E.E.* (London), part III, vol. 93, pp. 294–295; July, 1946.) Discussion of 569 of March.

621.396[.619+.621.53+.8 **2851**

The Calculation of Intermodulation Products by Means of a Difference Table—A. Bloch. (*Jour. I.E.E.* (London), part I, vol. 93, p. 326; July, 1946.) Abstract of 2163 of August.

621.396[.619+.621.53+.8 **2852**

Modulation Products—A Bloch. (*Wireless Eng.*, vol. 23, pp. 227–230; August 1946.) "Tables and formulas for the calculation of modulation products from valve characteristics are given which are similar to those customarily used for the determination of the amplitude of harmonics from a series of equidistant ordinates. The derivation of the method is also described."

621.396.619.018.41:534.43:621.395.61 **2853**

Simplified Frequency Modulation—G. G. Bruck. (Proc. I.R.E. and Waves and Electrons, vol. 34, p. 458; July, 1946.) Description of a circuit using a double triode as oscillator, amplifier, and discriminator, and having controlled negative feedback, which can be used as a frequency-modulation gramophone-pickup circuit controlled by variation of capacitance to the needle.

621.396.622.72 **2854**

Oscillation Hysteresis in Grid Detectors—E. E. Zepler. (*Wireless Eng.*, vol. 23, pp. 222–227; August, 1946.) "The conditions under which grid-leak detectors employing variable regeneration may exhibit oscillation hysteresis are discussed. A theory covering the principal effects responsible for hysteresis is given, together with its experimental verification. Various measures against oscillation hysteresis are recommended."

621.396.645.029.63 **2855**

Power Amplifiers with Disk-Seal Tubes—H. W. Jamieson and J. R. Whinnery. (Proc. I.R.E. and Waves and Electrons, vol. 34, pp. 483–489; July, 1946.) Experimental data are given for frequencies between 200 and 3000 megacycles. In the 200-megacycle region they agree well with class-C calculations using static characteristics. Amplifiers for 1000 megacycles are described, and factors limiting the performance at 3000 megacycles are discussed. Power gains up to 4 or 5 times and power outputs up to 17 watts have been obtained at 3000 megacycles. Transit-time effects such as the back heating of the cathode by returned electrons may contribute to the poor performance at high frequencies.

621.396.662 **2856**

The Design of Band-Spread Tuned Circuits for Broadcast Receivers—D. H. Hughes. (*Jour. I.E.E.* (London), part I, vol. 93, pp. 317–318; July, 1946.) Long abstract of 1803 of July.

621.397.64 **2857**

H. F. Wideband Amplifier—(*Radio Craft*, vol. 17, p. 645; June, 1946.) Sylvania intermediate-frequency chassis for television using 6AK5 tubes, center frequency 60 megacycles, bandwidth 9 megacycles.

539.16.08+621.318.572 **2858**

Electron and Nuclear Counters. [Book Review]—Korff. (*See* 3081.)

621.396.61 **2859**

Théorie des Oscillateurs. [Book Review]—Y. Rocard. France, 1941, 223 pp. (*Wireless Eng.*, vol. 23, p. 233; August, 1946.) "This book can be heartily recommended to anyone seriously interested in the subject of oscillations."

GENERAL PHYSICS

523.755:539.1 **2860**

Possibility of Emission of a Very Hard Radiation from the Solar Corona.—J. S. Shklovsky. (*Nature*, (London), vol. 157, p. 840; June 22, 1946.)

530.145 **2861**

An Attempt to Formulate a Divergence-Free Quantum Mechanics of Fields—G. Rayski. (*Nature*, (London), vol. 157, p. 873; June 29, 1946.)

534.131 **2862**

Reflection and Refraction of Non-Stationary Elastic Waves—V. Gogoladze. (*Compt. Rend. Acad. Sci.* (U.R.S.S.) vol. 49, pp. 322–325; November 20, 1945. In English.) "The present paper and [2863 and 2864 below] . . . contain a full treatment of the elastic wave reflection and refraction problem for arbitrary elastic media that are in contact along a plane. Also a theory of Rayleigh boundary waves developed."

534.131 **2863**

On Rayleigh Boundary Waves—V. Gogoladze. (*Compt. Rend. Acad. Sci.* (U.R.S.S.), vol. 49, pp. 400–403; November 30, 1945. In English.) A short mathematical paper on the spectrum of free vibrations of two different solid elastic media meeting along a plane. The necessary and sufficient condition for the existence of Rayleigh's boundary wave is established.

534.131 **2864**

General Formulae for the Reflexion and Refraction of Non-Stationary Elastic Waves—V. Gogoladze. (*Compt. Rend. Acad. Sci.* (U.R.S.S.), vol. 49, pp. 479–481; December 10, 1945. In English.) Elastic disturbances may be considered as an aggregate of longitudinal and transverse waves reflected and refracted through real and complex angles in the plane of separation between elastic media, consequently, as an aggregate of homogeneous and nonhomogeneous plane waves. General formulas for these waves are given. The horizontal component of energy flow in the nonhomogeneous waves has a constant direction, while the vertical component "may change its sign with time and at different points." See also 2862 above.

535.234 **2865**

Planck's Radiation Formula—D. G. Kendall: H. Dingle. (*Nature*, (London), vol. 157, p. 737; July 1, 1946.) Demonstration by Kendall that Planck's radiation formula is not a unique solution of the general integral equation considered by Dingle (*Nature*, (London), vol. 157, p. 515; April 20, 1946) and reply by Dingle.

535.313.2.08 **2866**

Screen-Line Tests of Paraboloidal Reflectors—D. H. Hamsher. (*Jour. Opt. Soc. Amer.*, vol. 36, pp. 291–295; May, 1946.) Theoretical and practical considerations of testing optical reflectors by photographing by reflection an illuminated screen bearing ruled lines.

535.43 2867

Modified Rayleigh Scattering in a Liquid—D. H. Rank. (*Jour. Opt. Soc. Amer.*, vol. 36, pp. 299–301; May, 1946.) Experimental investigation of the phenomenon of scattered light of modified frequency predicted by Brillouin. The λ3650 and λ4358 mercury lines were used, and scattering from benzene gave wavelength shifts in close agreement with the theoretical values.

535.434 2868

On the Theory of the Light Field in a Scattering Medium—A. Gershun. (*Compt. Rend. Acad. Sci.* (U.R.S.S.) vol. 49, pp. 556–557; December 20, 1945. In English.) In a turbid medium where the illumination is due to scattered light, the relative distribution of intensity may be considered uniform in all directions. This leads naturally to the exponential law of attenuation of light with increasing depth.

In sea water the attenuation of daylight with increasing depth is determined almost completely by the true absorption.

535.61-15:536.45:546.3 2869

Infra-Red Emissivity of Metals at High Temperatures—D. J. Price. (*Nature*, (London), vol. 157, p. 765; June 8, 1946.) Measured between 1000 degrees and 1500 degrees centigrade in a specially designed furnace.

537.523.4 2870

Incomplete Breakdown: a Cathode Deionization Effect—F. L. Jones. (*Nature*, (London), vol. 157, p. 480; April 13, 1946.) The "stepped" nature of the voltage change observed across a spark gap using very clean electrodes is discussed. Introduction of fine dust particles of certain oxides on the cathode destroys the "stepped" phenomenon and permits full breakdown of spark-gap insulation. It is concluded that, for complete breakdown, continuous electron emission at or near the cathode is required during the whole breakdown process and not merely in the initial stages.

537.525:538.551.25 2871

Characteristic Electric Oscillations of a Low Pressure Mercury Arc—B. L. Granovsky and L. N. Bykhovskaya. (*Compt. Rend. Acad. Sci.* (U.R.S.S.) vol. 49, pp. 339–342; November 20, 1945. In English.) Short account of experiments on oscillations in the frequency range 10^3 to 10^6 cycles in a circuit "consisting only of a constant electromotive force, ohmic resistance, and discharge gap." In these experiments the discharge gap was a mercury arc and the existence of four different types of oscillation was established, (a) irregular deviations of the voltage from its normal value in the case of a freely moving cathode spot, (b) irregular oscillations at higher frequencies in the case of an anchored cathode spot, (c) regular oscillations in the low radio-frequency range (10^4 to 10^6 cycles, and (d) regular oscillations in the range of sound frequencies (3000 to 300 cycles and lower). See also 2872 below.

537.525:538.551.25 2872

The Generation of High-Power Electric Oscillations by a Low Pressure Discharge—B. L. Granovsky and T. A. Suetin. (*Compt. Rend. Acad. Sci.* (U.R.S.S.) vol. 49, pp. 410–413; November 30, 1945. In English.) Brief summary of results of a study of the generation of oscillations by gas-discharge tubes having a perforated diaphragm or a narrow neck dividing the anode from the cathode regions (such tubes are here given the name "stenotrones"). The form of these oscillations depends on temperature, pressure, shape of tube, nature and density of gas discharge and upon the external circuit. Frequencies of 15 to 100 kilocycles and useful oscillatory powers up to 1 kilowatt were obtained. See also 2871 above.

537.533.72+621.385.833 2873

Focusing of Electrons in Two Dimensions by an Inhomogeneous Magnetic Field—K. Siegbahn and N. Svartholm. (*Nature*, (London), vol. 157, pp. 872–873; June 29, 1946.) Description of a method combining several of the useful properties of the semicircular and lens methods of focusing β rays.

537.533.72+621.385.833 2874

Optical Characteristics of a Two-Cylinder Electrostatic Lens—Goddard. (*See* 2998.)

537.533.72+621.385.833 2875

A Note on the Petzval Field Curvature in Electron-Optical Systems—Goddard. (*See* 2999.)

537.564 2876

Stepped Ionization of Hydrogen by Electronic Impact—B. Yavorsky. (*Compt. Rend. Acad. Sci.* (U.R.S.S.). vol. 49, pp. 250–253; November 10, 1945. In English.) Short mathematical paper on a method of computing the cross-section for ionization of the hydrogen atom.

537.591.5 2877

Mesotron Intensity as a Function of Altitude—P. S. Gill. (*Nature*, (London), vol. 157, p. 691; May 25, 1946.) A slight hump (maximum) occurs in the intensity versus pressure curve at 500 millibars.

538.1 2878

On Certain Non-Linear Phenomena Resulting from the Superposition of Mutually Perpendicular Magnetic Fields—G. S. Gorelik. (*Bull. Acad. Sci.* (U.R.S.S.), sér. phys., vol. 8, no. 4, pp. 172–188; 1944. In Russian.) Complete paper, of which an English summary was abstracted in 3073 of 1945.

538.11 2879

The Unit-Pole Definition of Magnetic Field Strength—G.W.O.H. (*Wireless Eng.*, vol. 23, pp. 207–210: August, 1946.) The problem of reconciling this definition with the fact that H is not a directly measurable quantity is discussed for media of permeability other than unity.

538.31 2880

On the Parametric Vibrations of an Iron Body in an Alternating Magnetic Field—S. M. Rytoff. (*Bull. Acad. Sci.* (U.R.S.S.), sér. phys., vol. 8, no. 3, pp. 150–155; 1944.) In Russian.) Complete paper, of which an English summary was noted in 3074 of 1945. For another Russian version see 2546 of September.

538.56:530.12:531.51 2881

Radiation of Gravitational Waves by Electromagnetic Waves—L. M. Brekhovskich. (*Compt. Rend. Acad. Sci.* (U.R.S.S.), vol. 49, pp. 482–485; December 10, 1945. In English.) The decrease in flux of electromagnetic energy due to gravitational radiation for a spherical electromagnetic wave is calculated for Einstein's cylindrical world and for a spherically istropic world, and is found to be unobservable.

539.153:538.221 2882

Collective Electron Assemblies in a Metal with Overlapping Energy Bands: Part 1, General Theory; Part 2, The Occurrence of Ferromagnetism—W. Band. (*Proc. Camb. Phil. Soc.*, vol. 42, part 2, pp. 139–144 and 144–155; June, 1946.) In part 1 it is shown that, in a metal with overlapping energy bands, one of which is nearly full and the other nearly empty, there exists a critical temperature below which spontaneous magnetization will be present. In part 2 it is shown that this concept is useful in systematizing the Curie-point data not only for pure ferromagnetic elements but also for the ferromagnetic alloys.

541.135:537[.226+.228.2 2883

On the Dielectric Property and Electrostriction of Solutions of Electrolytes—O. K. Davtjan. (*Compt. Rend. Acad. Sci.* (U.R.S.S.), vol. 49, pp. 575–577; December 20, 1945. In English.) A theoretical paper which establishes "that the change in the dielectric constant of a polar liquid consequent upon the dissolution of an electrolyte is proportional to its electrostriction."

A formula is derived expressing the relation between the dielectric constant and concentration of an electrolyte. Satisfactory agreement with experimental data is found.

621.317.4:621.318.2 2884

The Magnetic Potentiometer Study of Permanent Magnets—Bates. (*See* 2939.)

621.384 2885

On Resonance Phenomena Associated with the Movement of a Relativistic Particle in the Cyclotron—A. Andronov and G. Gorelik. (*Compt. Rend. Acad. Sci.* (U.R.S.S.), vol. 49, pp. 640–642; December 30, 1945. In English.) A theoretical analysis of the variation of energy of a charged particle with the intensity of magnetic field in a cyclotron. A resemblance to the curve of ferro-resonance is pointed out.

537+538](075) 2886

Electricity and Magnetism for Students. [Book Review]—S. R. Humby. John Murray, London, second edition 1945, 6s. 6d. (*Nature*, (London), vol. 157, p. 714; June 1, 1946.) ". . . Covers all the essential work for higher school certificate and university scholarship examinations, and treats the difficulties of electrostatic theory exceptionally well."

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.165:523.746"1946.01/.02" 2887
Cosmic Rays and the Great Sunspot Group of January 29–Febuary 12, 1946—A. Duperior and M. McCaig. (*Nature*, (London), vol. 157, p. 477; April 13, 1946.) Large variations in intensity of cosmic rays were observed during the passage of a large sunspot group, a large decrease in intensity coinciding with the peak of the associated magnetic storm.

523.7 2888
Magnetism of the Sun—K. Mital. (*Sci. Culture*, vol. 11, pp. 671–677; June, 1946.) A discussion of present-day knowledge and theoretical explanations of observed aspects of the sun's magnetic field. The field and polarity associated with sunspots, and convection currents in the sun itself are discussed. The relation of the general magnetic field to that of a uniformly magnetized sphere is examined.

523.72 2889
Cause Radio Disturbances—(*Sci. News Lett.*, Washington, vol. 49, p. 245; April 20, 1946.) Clouds of electrically charged gases reaching the earth from the sun were discovered by a pulse ranging method during recent magnetic-ionospheric storms.

523.746 2890
The Magnetic Field of the Sun Spots—L. E. Gurevich and A. I. Lebedinsky. (*Compt. Rend. Acad. Sci.* (U.R.S.S.), vol. 49, pp. 92–94; October 20, 1945.) Explanation of the magnetic field observed in sunspots in terms of the flow of ionized gas towards the axis of the spot. The gas, crossing the initial (weak) field of the sun has currents induced in it, resulting in an enhanced magnetic field along the axis of the spot. The field builds up slowly in a time comparable with the life of the spot.

523.746:621.396.11:551.51.053.5 2891
Sunspots and Radio Communication—(*See* 3015.)

523.78:551.51.053.5 2892
Solar Eclipses and Radio Investigations of the Ionosphere—Ya. L. Al'pert and B. N. Gorozhankin. (*Bull. Acad. Sci.* (U.R.S.S.), sér. phys., vol. 8, no. 2, pp. 85–108; 1944. In Russian.) Complete paper, of which an English summary was abstracted in 2521 of 1945.

523.78"1945.07.09":551.51.053.5:621.396.11 2893
On the Results of Radio-Observations during the Sòlar Eclipse (Corouscular and Ultra-Violet) of July 9, 1945—Ya. L. Al'pert and B. N. Gorozhankin. (*Compt. Rend. Acad. Sci.* (U.R.S.S.), vol. 49, pp. 254–258; November 10, 1945. In English.) Brief account of equivalent height and azimuth measurements on 3.8 megacycles and 6 megacycles over a sender-receiver distance of 37 kilometers. The azimuth observations showed marked variations during the eclipse period, and it is suggested that these were due to bending of the F_2 layer during the optical eclipse. The results in general confirm the view that solar ultra-violet light governs E-layer ionization and "that the corpuscular radiation of the sun is not the agent determining the fundamental state of ionization of any of the regions of the ionosphere and that its action is purely perturbative in nature . . . [However,] from the results of our experiments it may be concluded that the corpuscular radiation of the sun, in particular for particles with velocities of the order of 500 kilometers, affects the ionosphere."

525.24:523.7 2894
Persistent Solar Rotation Period of 26.875 Days and Solar-Diurnal Variation in Terrestrial Magnetism—J. Olsen. (*Nature*, (London), vol. 157, p. 621; May 11, 1946.) Observations of the solar-diurnal variation in the horizontal force of the terrestrial magnetic field at Godhavn, Greenland, covering the years 1926 to 1940 establish a definite periodicity of 26.875 days. The effect vanishes in winter and has not been observed south of the auroral zone. Probable explanations are discussed.

550.37:621.315.28 2895
Earth Currents in Short Submarine Cables—D. W. Cherry and A. T. Stovold. (*Nature*, (London), vol. 157, p. 766; June 8, 1946.) Tests on submarine cables between Great Britain and the Continent earthed at the far shore show that voltages between cable and earth vary with the same periodicity as the tides.

550.38 2896
On the Origin of Terrestrial Magnetism—J. Frenkel. (*Compt. Rend. Acad. Sci.* (U.R.S.S.), vol. 49, pp. 98–101; October 20, 1945. In English.) An hypothesis to explain the existence and magnitude of the earth's magnetic field is given in terms of convection currents set up in the core of the earth, which is assumed to be of molten metal of relatively low viscosity. These convection currents in the presence of a weak "adventitious" field give rise to a more powerful magnetic field by a process of "self-excitation." The theory gives results which are high by a factor of 10 or even more compared with the observed values, but it is pointed out that the theory is incomplete and does not take account of many possibly important factors. See also 2890 above.

551.51.053.5:550.38 2897
On Currents in the Ionosphere which Cause Variations in the Earth's Magnetic Field—I. E. Tamm. (*Bull. Acad. Sci.* (U.R.S.S.), sér. phys., vol. 8, no. 2, pp. 30–41; 1944. In Russian.) Complete paper, of which an English summary was abstracted in 2523 of 1945.

551.51.053.5:550.38 2898
Two Anomalies in the Ionophere—E. V. Appleton. (*Nature*, (London), vol. 157, p. 691; May 25, 1946.) Ionization in the F_2 layer is not symmetrical with respect to either geographic latitude or geographic longitude. Geomagnetic influences in the F_2 layer are suggested by the symmetry which obtains when magnetic dip is used in place of geographic latitude as a basis of comparison with F_2 ionization.

551.51.053.5:621.396.11 2899
Ionosphere Storm Effects in the E Layer—T. W. Bennington. (*Nature* (London), vol. 157, pp. 477–478; April 13, 1946.) During the course of, or just prior to, an ionospheric storm, a low-pitched "rumble" is heard from high-power transmitting stations within the skip zone. From the nature of the signals it is concluded that they are due to variations in the ionic clouds in the E layer, and that these clouds are affected by the corpuscular radiation from the sun which causes the ionospheric storm.

551.51.053.5:621.396.11 2900
Maximum Values of Radio Field Intensity on Vertical Reflection from the Ionosphere, and an Evaluation of the Coefficient of Reflection—Kessenikh. (*See* 3014.)

551.51.053.5:621.396.11 2901
On the Refractive Index of an Ionized Gas (Ionosphere)—V. L. Ginsburg. (*Bull. Acad. Sci.* (U.R.S.S.), sér. phys., vol. 8, no, 2, pp. 76–84; 1944. In Russian.) Complete paper, of which an English summary was abstracted in 2517 of 1945.

551.51.053.5:621.396.91 2902
Ionosphere Measuring Equipment—Sulzer. (*See* 2983.)

551.57:621.396.82:629.135 2903
Flight Research on Precipitation Static—Cleveland. (*See* 3038).

551.594.5:535.33 2904
The Auroral Spectrum—S. K. Mitra. (*Nature*, (London), vol. 157, p. 692; May 25, 1946.) The spectra of the aurora and of the luminescent night sky are compared with those of atmospheric gases in a discharge tube. In the tube the glass walls absorb the products of bombardment, but in the upper atmosphere these persist and cause radiation by interaction. Differences between the auroral and night-sky spectra are due to higher collision frequency at the level of the aurora.

LOCATION AND AIDS TO NAVIGATION

519.2 2905
The General Case of Locating a Point on a Plane by Three Angle Measurements—Yudin. (*See* 2959.)

621.3(43) 2906
German Industrial Techniques—(*See* 2927.)

621.396.9 2907
The Military Application of Radar—E. G. Bowen. (*Proc. I.R.E.* (Australia), vol. 7, pp. 4–10; May, 1946.) Lecture giving a popular description and the history of development of radar for ground, ship, and aircraft use. For report of previous lecture see 1854 of July.

621.396.9 2908
Rotary Wave Radar—W. van B. Roberts. (*Electronics*, vol. 19, pp. 130–133; July, 1946.) A general description of a continuous-wave radar system using circularly polarized waves. The system has advantages in low-power applications requiring minimum weight and bulk.

621.396.9 2909

Aircraft Radar—V. Zeluff. (*Sci. Amer.*, vol. 174, pp. 204–206; May, 1946.) A brief general description of teleran, ground control approach, lanac, and loran.

621.396.9 2910

Demonstration of a Marine Radar Set—(*Engineer* (London), vol. 181, pp. 583–584; June 28, 1946.) Primarily for short-range navigation, and complying with British Ministry of Transport specification. The set, now in quantity production, consists of scanner, console with receiver, and plan-position indicator display, transmitter, and motor generator set with control board. The wavelength of the set is in the 3-centimeter band, and the peak power is 50 kilowatts. Manual control of scanning is provided for, and an automatic warning unit is fitted, giving audible warning of the presence of an object in any direction within range limits 3000 to 6000 yards.

621.396.932 2911

Radio Aids to Marine Navigation—(*Engineer* (London), vol. 181, pp. 425–427; May 10, 1946.) A brief description of direction-finding systems and the shipborne radar installed on H.M.S. Fleetwood for a trial blind run in the Solent.

621.396.932/.933].24 2912

Consol—J. E. Clegg. (*Wireless World*, vol. 52, pp. 233–235; July, 1946.) A description of a long-range radio navigational aid. Seventy-four beams are produced by three aerials on a two-mile baseline, the field being divided into areas of "dot" and "dash" modulation. The equisignal beams are rotated through about 10 degrees per minute, and the time at which the beam passes through the receiving station (measured in terms of the number of dots and dashes received since the last marking signal, a continuous tone) indicates the bearing from the transmitter. Maps and charts are provided at the receiving station for the interpretation of bearings.

The operational frequency range is 250 to 420 kilocycles, the reliable range 1000 miles over sea and 600 miles over land, by day, with an accuracy of about 0.3 degree. At night the range is increased and the accuracy reduced to 1 to 3 degrees, depending on the sector. Ambiguities on bearing are normally easy to resolve by the use of other available data.

621.396.933.2 2913

Evaluation of Night Errors in Aircraft Direction Finding, 150–1500 Kilocycles—H. Busignies. (*Elec. Commun.*, vol. 23, pp. 42–62; March, 1946.) Description of a method by which a pilot can determine the accuracy of night bearings obtained by aircraft radio compass and the effect of the aircraft's passing through fields resulting from reflections from the *E* layer or from mountains. Night error on the ground and at altitude is discussed, considering the simultaneous presence of the direct wave, sky wave, and sky wave reflected from the ground. All cases of polarization are examined briefly to indicate the numerous effects which may be encountered and a number of rules are given for direction finding at night over land and sea, with diagrammatic maps showing safe and unsafe areas of operation.

621.396.933.2 2914

Discussion on "A New Type of Automatic Radio Direction Finder"—C. C. Pine and H. Busignies. (PROC. I.R.E. AND WAVES AND ELECTRONS, vol. 34, p. 457; July, 1946.) Discussion of 3543 of 1945, referring to earlier patents issued to Busignies, with reply by Pine.

621.396.933.23 2915

Microwave Approach and Landing System—W. T. Spicer. (*Elec. Ind.*, vol. 5, pp. 52–57; August, 1946.) Description of equipment for the blind landing of aircraft that carry only voice communication apparatus. It consists of two microwave radar sets: (a) search system on 3000 megacycles that gives a polar radar map of 30 miles radius and (b) precision system on 10,000 megacycles that covers a sector 20 degrees in azimuth and 7 degrees in elevation over the runway, with 10 miles range, and gives azimuth, elevation, and range indications. The ground observer gives verbal instructions to the aircraft.

621.396.9 2916

Radar—Radiolocation Simply Explained. [Book Review]—R. W. Hallows. Chapman and Hall, London, 140 pp., 59 figures, 7s. 6d. (*Elec. Rev.* (London), vol. 138, p. 848; May 31, 1946.) ". . . not highly technical, but contains a clear exposition of the basic principles of the subject."

621.396.9 2917

Radar for Merchant Ships. [Book Review]—H. M. Stationery Office, 1946, 9d. (*Electrician*, vol. 136, p. 1598; June 14, 1946.) Includes a specification suitable for adoption by manufacturers.

MATERIALS AND SUBSIDIARY TECHNIQUES

531.788.1 2918

A Knudsen Absolute Manometer—S. E. Williams. (*Jour. Sci. Instr.*, vol. 23, pp. 144–146; July, 1946.) Describes a new design. The gauge is capable of absolute measurement of pressures between 10^{-4} millimeters and 10^{-6} millimeters of mercury.

531.788.6 2919

Thermocouple Vacuum Gage—H. Robinson and M. C. Flanagan. (*Gen. Elec. Rev.*, vol. 49, pp. 42–44; May, 1946.) Description of the arrangement and performance of a direct-reading gauge for the 1 to 200 micron range.

531.788.7 2920

Application of the Ion Gage in High Vacuum Measurement—H. E. Van Valkenburg. (*Gen. Elec. Rev.*, vol. 49, pp. 38–42; June, 1946.) An electronic control panel has been developed for use with the ionization gauges to give continuous and stable operation over the range 10^{-4} to 10^{-8} millimeters of mercury. Details are given of the stabilizing and protective circuits used and practical operation is discussed.

535.215:546.3 2921

Photoelectric Properties of Metals in a Finely Divided State—L. J. Reimert. (*Jour. Opt. Soc. Amer.*, vol. 36, pp. 278–283; May, 1946.) Investigation of black surfaces (produced by distillation at a pressure of several millimeters of mercury) of Cd, Zn, Sb, over the wavelength range 0.24 to 0.44μ and of Na from 0.40μ at 0.96μ. The dependence of the photoelectric output and the threshold on the nature of the surfaces is discussed.

535.37 2922

The Effect of Wave-Length Distribution on the Brightness of Phosphors—R. T. Ellickson. (*Jour. Opt. Soc. Amer.*, vol. 36, pp. 261–264; May, 1946.) A simple graphical method is given for estimating the visual efficiency of the emitted light from a phosphor with an emission curve that can be represented by a Gauss error function.

535.37 2923

Light Sum of Phosphors under Thermal and Infra-Red Stimulation—R. T. Ellickson. (*Jour. Opt. Soc. Amer.*, vol. 36, pp. 264–269; May, 1946.) Measurements show that the ratio of the light sums obtained by infra-red irradiation or by heating the phosphor can vary from 1 to 30 according to the phosphor. This effect should be taken into account in using glow curves to determine the electron trap distributions in phosphors.

538.213:546.74:538.56.029.64 2924

Magnetic Permeability of Nickel in the Region of Centimetre Waves—I. Simon. (*Nature*, (London), vol. 157, p. 735; June 1, 1946.) μ decreases from 7.7 at $\lambda=20$ centimeters to 1.2 at $\lambda=3.2$ centimeters as measured on films 1000–2000 angstroms thick. The static permeability was found to decrease from 22 for 2300 angstroms thickness to unity at zero thickness.

546.32.85+546.39.85]:537.228.1 2925

ADP and KDP Crystals—W. P. Mason. (*Bell Lab. Rec.*, vol. 24, pp. 257–260; July, 1946.) Piezoelectric crystals of ammonium dihydrogen phosphate containing no water of crystallization are recommended for use as a substitute for Rochelle salt. The isomorphous salt potassium dihydrogen phosphate has similar properties, and the crystal structure is discussed. See also 1260 of May (Mason).

549.6:661.312.1:66.083.4 2926

Action of Water and Potassium Solutions under Pressure on Various Kinds of Silica—J. Wyart. (*Compt. Rend. Acad. Sci.* (Paris), vol. 220, pp. 830–832; June 4, 1945.) A brief account of a study of the crystalline forms appearing as a result of the action of water and of 0.01 mol KOH on fused silica.

621.3(43) 2927

German Industrial Techniques—(*Electronics*, vol. 19, pp. 200–206; July, 1946.) Notes on a number of developments connected with wired wireless; deposition of metallic films, radar, and ceramics.

621.3.017[.143+.39 2928

Several After-Effect Phenomena and Related Losses in Alternating Fields—J. L. Snoek and F. K. du Pré. (*Philips Tech. Rev.*, vol. 8, pp. 57–64; February, 1946.) A survey of the causes and effects of the phenomena in dielectrics and ferromagnetic materials.

621.315.229 2929

Jacketing Materials for High-Frequency Transmission Lines—A. J. Warner. (*Elec. Commun.*, vol. 23, pp. 63–69; March, 1946.) The relative merits of a number of plastics and other materials are discussed. Test procedures are also outlined. See also 631 of March (Warner).

621.315.3 2930

Methods of Removing the Insulating Film from Formex Wire—E. J. Flynn and G. W. Young. (*Gen. Elec. Rev.*, vol. 49, pp. 8–15; June, 1946.) Tests on various types of solvent give the following results: aqueous solutions of salts and alkalis are ineffective; liquid organic mixtures with ammonium hydroxide, formic acid solutions, and certain acid pastes are rapid and do not cause corrosion, but need care in handling; immersion in certain molten compounds, glass or solder is extremely rapid; of these 50–50 lead-tin solder at a temperature just over 500 degrees centigrade has proved most generally useful. Data and necessary precautions are stated for all the methods investigated.

621.315.61:546.287 2931

New Electrical Materials—I. (*Electrician*, vol. 137, pp. 383–386; August 9, 1946.) Notes on organo-silicon compounds, including silicones.

621.315.61:621.396 2932

New Dielectric and Insulating Materials in Radio Engineering—(*Engineer* (London), vol. 181, pp. 519–520; June 7, 1946.) Report of the Institution of Electrical Engineers discussion on new radio-frequency insulating materials, particularly hydrocarbon plastics and ceramics. Disadvantages of the hydrocarbons are their widely varying mechanical properties and their low temperature-resistance. Progress is being made in overcoming these deficiencies. Magnesium silicate derivatives are used in ceramics, and a closer study of titanium dioxide has yielded better capacitor dielectrics. Titanates of the alkaline earth metals offer scope for development. For another account see *Electrician*, vol. 136, pp. 1519–1520; June 7, 1946.

621.315.611 2933

The Formation of Ionized Water Films on Dielectrics under Conditions of High Humidity—R. F. Field. (*Jour. Appl. Phys.*, vol. 17, pp. 318–325; May, 1946.) "When a dielectric is placed in an atmosphere of 100 per cent relative humidity, an ionized film of water forms, whose conductivity at the end of one minute is within a factor of ten of its equilibrium value, which is usually attained within an hour. This equilibrium conductivity ranges from essentially zero for certain hydrocarbon waxes, silicone resins and silicone-treated glass to 100 micromhos for ordinary glass and quartz. The ionized water film also produces interfacial polarization at its interface with the dielectric, which produces a marked increase in both capacitance and dissipation factor at audio frequencies. This polarization builds up in the same manner as the conductivity. Its relaxation frequency appears to be in the audio range."

621.315.613.1 2934

Physical Properties of Mica—(*Nature*, (London), vol. 157, pp. 849–850; June 22, 1946.) Survey of American work leading to the conclusion that none of the species of mica has fixed and reproducible physical properties, since these are largely dependent on heat treatment, presence of impurities, and other factors. Main reference is to work of Hidnert and Dickson (*see* 1559 of June).

621.315.613.8.011.5:546.431.824 2935

Dielectric Constant of Barium Titanate as a Function of Strength of an Alternating Field—B. M. Wul and I. M. Goldman. (*Compt. Rend. Acad. Sci.* (U.R.S.S.), vol. 49, pp. 177–180; October 30, 1945. In English.) An experimental study has established that below a critical temperature (about 80 degrees centigrade) the dielectric constant varies with the applied electric field. The effect is not due to the production of ionization in the air enclosed in any pores in the material, but is due to a change in the physical properties of the substance. The critical temperature, which depends somewhat on the annealing process, corresponds to the temperature at which the dielectric constant reaches a maximum. It is suggested that below the critical temperature the substance is pyroelectric. An abrupt variation in the specific heat of the substance at about 125 degrees centigrade has also been observed.

621.315.616 2936

Synthetic Rubbers and Plastics: XI. (Part II) Water and the High Polymer—F. T. White. (*Distrib. Elec.*, vol. 19, pp. 143–145; July, 1946.) Further discussion of factors affecting the water affinity of high polymers, with examples of behavior for several types of molecular structure. For part 1 of section XI see 1560 of June. To be continued.

621.315.616.029.64 2937

Dielectric Behavior of 'Polythene' at Very High Frequencies—J. G. Powles and W. G. Oakes. (*Nature*, (London), vol. 157, pp. 840–841; June 22, 1946.) The power factor decreases for wavelengths below 10 centimeters; polythene may be used with confidence as a low loss dielectric at 1-centimeter wavelength. A graph shows measurements of power factor versus frequency over the range 10^5 to 2.10^{10} cycles.

621.315.616.9:536.41 2938

Thermal Expansion and Second-Order Transition Effects in High Polymers: Part 3 —Time Effects—R. S. Spencer and R. F. Boyer. (*Jour. Appl. Phys.*, vol. 17, pp. 398–404; May, 1946.) The apparent second-order transition in polystyrene is shown to be a rate-effect.

"At ordinary rates of heating below the apparent transition temperature, or at more rapid rates near and above the transition temperature, polystyrene exhibits a cubical thermal expansion coefficient of about 2.7×10^{-4} per degree centigrade, and this value is not dependent on the heating rate as long as it is rapid enough. This fact suggests that two mechanisms operate in the thermal expansion of polystyrene, at markedly different rates, one resulting in almost instantaneous expansion, even at room temperature, and the other being strongly temperature dependent and contributing to the expansion under normal rates of hearing only at higher temperatures."

For previous parts see 3605 of 1944 and 350 of February.

621.317.4:621.318.2 2939

The Magnetic Potentiometer Study of Permanent Magnets—L. F. Bates. (*Phil. Mag.*, vol. 36, pp. 297–318; May, 1945.)

621.357.7:[621.882.2/.3 2940

Clearance Between Nut and Screw Prior to Plating—J. Bradshaw. (*Electronic Eng.*, vol. 18, p. 259; August, 1946.) The basis for calculations, with mnemonics and a table of values for B.A. and Whitworth threads.

621.357.7:669.55.6 2941

Electrodeposition of Tin-Zinc Alloys—R. M. Angles. (*Engineering* (London), vol. 161, p. 427; May 3, 1946.) Composition of the electrolyte, and precautions in application. Reference is made to an article by Angles and Kerr (2599 of September).

621.396.6:551.5:629.135 2942

The Effects of Atmospheric Conditions on Aircraft Radio Equipment—Honnor. (*See* 3144.)

621.791.3 2943

Soft Solders—L. G. Earle. (*Metal Ind.*, (London), vol. 66, pp. 308–311 and 322–325; May 18, and 25, 1945.) Determination of jointing capacity by the Kollagraph.

621.791.3:669.65.4 2944

An Engineering Approach to Soldering with Tin-Lead Alloys: Part 1—A. Z. Mample. (*Metals and Alloys*, vol. 21, pp. 702–707; March, 1945.)

621.793 2945

Metal Coatings on Ceramics—E. Rosenthal. (*Electronic Eng.*, vol. 18, pp. 241–242, 262; August, 1946.) A review of methods used, with special reference to the advantages of the method of firing on a paint consisting of a mixture of precious-metal oxides (which reduce on heating) with a ceramic flux. See also 2613 of September (Wein).

668.31(213) 2946

Fortified Glues—(*Sci. Amer.*, vol. 174, p. 203; May, 1946.) Resistant to tropical conditions.

669.45:621.315.221 2947

[Chemical] Analysis of Cable Sheathing Alloys—G. M. Hamilton. (*Nature*, (London), vol. 157, p. 875; June 29, 1946.) A method of dissolving lead alloy (sheathing) containing up to 2 per cent tin, 0.8 per cent antimony and 0.25 per cent cadmium, with a solution of 30 per cent hydrogen peroxide and glacial acetic acid.

679.5 2948

Development of Industrial Plastics—(*S. Afr. Eng.*, vol. 57, pp. 132–133; June, 1946.) A history of the development of plastics with brief notes on the properties of some of the more recent melamine resins.

679.8.053 2949

A Simple Saw for Hard Materials [Quartz etc.]—W. A. Wooster. (*Jour. Sci. Instr.*, vol. 23, p. 131; June, 1946.)

539.23 2950
Thin Films and Surfaces. [Book Review]—W. Lewis. English University Press, London, 70 pp., 15s. (*Jour. Sci. Instr.*, vol. 23, p. 163; July, 1946.)

621.396.611.21:549.514.1 **2951**
Quartz Crystals. [Book Review]—R. A. Heising (Editor). D. Van Nostrand, New York, 563 pp., $6.50. (*Elec. Ind.*, vol. 5, pp. 110, 112; July, 1946.) Seventeen chapters by members of the Bell Telephone Laboratories. "... complete to the point of being exhaustive ... a valuable compendium of quartz crystal information."

679.5:621.3 **2952**
Plastics for Electrical and Radio Engineers. [Book Review]—W. J. Tucker and R. S. Roberts. Technical Press, Kingston, Surrey, 12s. (*Engineering* (London), vol. 161, p. 482; May 24, 1946.) Written with "informed judgment" and a "wide knowledge of the requirements of electronic equipment." A very favorable review. See also 1896 of July.

MATHEMATICS

517.512.4:621.392.41.015.3 **2953**
On Transients in Homogeneous Ladder Networks of Finite Length—W. Nijenhuis. (*Physica* (Eindhoven), vol. 9, pp. 817–831; September, 1942. In English.) See 2836 above. Contains a sine-series expansion for Bessel functions.

517.9 **2954**
On the Stability of Systems of Differential Equations—R. Bellman. (*Proc. Nat. Acad. Sci.*, (Washington), vol. 32, pp. 190–193; June, 1946.)

518.5 **2955**
Slide-Disk Calculator—G. S. Merrill. (*Gen. Elec. Rev.*, vol. 49, pp. 30–33; June, 1946.) The most efficient measure of the dispersion of a set of measurements is given by the root-mean-square deviation from the arithmetic mean. The calculator, based on the theorem of Pythagoras, affords a quick and simple means of obtaining this result. See also 2956 below.

518.5 **2956**
A Circular Slide Rule—J. R. Dempster. (*Science*, vol. 103, p. 488; April 19, 1946.) For root-mean-square operations. See also 2616 of September (Mowell), and 2955 above.

518.5:517.512.2 **2957**
A Machine for the Summation of Fourier Series—G. Hägg and T. Laurent. (*Jour. Sci. Instr.*, vol. 23, pp. 155–158; July, 1946.) Principally for Fourier synthesis in X-ray crystallography.

518.5:621.38 **2958**
Super Electronic Computing Machine—Burks. (*See* 2995.)

519.2 **2959**
The General Case of Locating a Point on a Plane by Three Angle Measurements. —M. I. Yudin. (*Compt. Rend. Acad. Sci.* (U.R.S.S.), vol. 49, pp. 472–475; December 10, 1945. In English.) An extension of the author's paper (*Bull. Acad. Sci.* (*U.R.S.S.*), sér. géogr. et géophys., vol. 8, nos. 2–3, p. 96 on; 1944. In Russian.) to the case where the errors in angular measurement are not independent. Formulas are given which determine the position of the most probable point and the accuracy achieved. Aerodynamical and aural direction-finding applications are mentioned.

519.251.8 **2960**
Linear 'Curves of Best Fit'—A. E. W. Austen and H. Pelzer. (*Nature*, (London), vol. 157, pp. 693–694; May 25, 1946.) Applicable when both parameters are subject to errors of measurement.

621.392 **2961**
On Approximate Integration of van der Pol's Equation—Kazakevich. (*See* 2834.)

621.395.4 **2962**
The Probability Distributions of Sinusoidal Oscillations Combined in Random Phase—M. Slack. (*Jour. I.E.E.* (London) part I, vol. 93, p. 278; June, 1946.) Abstract of 1908 of July.

MEASUREMENTS AND TEST GEAR

621.317.3.029.63/.64 **2963**
Radio Measurements in the Decimetre and Centimetre Wavebands—R. J. Clayton, J. E. Houldin, H. R. L. Lamont, and W. E. Willshaw. (*Jour. I.E.E.* (London), part I, vol. 93, pp. 279–282; June, 1946.) Long abstract of 1914 of July.

621.317.32:621.3.015.33 **2964**
The Influence of Irradiation on the Measurement of Impulse Voltages with Sphere-Gaps—J. M. Meek. (*Jour. I.R.E.* (London), part I, vol. 93, pp. 318–319; July, 1946.) Long abstract of 2624 of September.

621.317.35 **2965**
Non-Inductive Wave Analyser Circuits of Constant Q—H. G. Yates. (*Engineer* (London), vol. 181, pp. 515–516; June 7, 1946.) Vibration problems in engineering require a wave analyser to track the component vibrations to their sources, and use is made of amplifier and resistance-capacity feedback bridge. Various modifications of this arrangement are dealt with briefly.

621.317.35 **2966**
Complex Waveforms—H. Moss. (*Electronic Eng.*, vol. 18, pp. 243–250; August, 1946.) The general method of harmonic analysis is discussed, and Fourier expansions for a large number of waveforms are tabulated. Notes are given on the production of certain of these waveforms. Conclusion of series; for previous parts see 2244 of August and back references.

621.317.361+621.396.611.21 **2967**
Duplex Crystals—(*Elec. Ind.*, vol. 5, pp. 63, 97; August, 1946.) See 1582 of June (Lane).

621.317.42 2968
A New Type of Magnetometer :Oersted-Meter;—I. L. Berstein. (*Bull. Acad. Sci.* (U.R.S.S.), sér. phys., vol. 8, no. 4, pp. 189–193; 1944. In Russian.) Complete paper, of which an English summary was abstracted in 2733 of 1945.

621.317.42 **2969**
Fluxmeter Method of Measurement—H. A. Miller. (*Electrician*, vol. 136, pp. 1577–1579; June 14, 1946.) The theory of the Grassot fluxmeter and the effect of a shunting resistance.

621.317.7:621.396.61 **2970**
Auxiliary Apparatus at the Amateur Station—W. H. Allen. (*R.S.G.B. Bull.*, vol. 22, pp. 20–22; August, 1946.) Practical information on the construction of simple test equipment including absorption and heterodyne frequency meters, monitor, and artificial aerial.

621.317.725:621.385 **2971**
Historic Firsts: Vacuum-Tube Voltmeter —(*Bell Lab. Rec.*, vol. 24, pp. 270, 274; July, 1946.)

621.317.727 **2972**
Direct Current Potentiometers—S. Holmqvist. (*Ericsson Rev.*, vol. 23, no. 1, pp. 35–37; 1946.) Description of a new potentiometer in which accuracy of measurement is not affected by switch transition resistance. A modification is described for use in the measurement of two potential differences or currents.

621.317.76 **2973**
A Standard of Frequency and Its Applications—C. F. Booth and F. J. M. Laver. (*Jour. I.E.E.* (London), part III, vol. 93, pp. 223–241; July, 1946.) An historical survey of the development of frequency standards, an analysis of the factors affecting their design, and a description of British Post Office apparatus giving frequencies known to $\pm 1\times 10^{-8}$. This apparatus consists of one fork-controlled oscillator and four groups of three quartz oscillators (one group of *AT*-cut 1000-kilocycle plates, three of *GT*-cut 100-kilocycle plates with various types of mounting). The oscillator outputs are selected to control frequency-dividers which reduce the frequency to 1 kilocycle for driving phonic-wheel clocks, the errors of which are measured by comparison with Rugby (GBR) time signals, determined by astronomical observation. Three of the twelve quartz oscillators are calibrated directly in terms of time and the remainder are compared with them.

Details are given of the crystal holders, oscillator circuits, temperature-control arrangements, and methods of intercomparison of the various oscillator frequencies.

621.317.761 **2974**
A Heterodyne Frequency Meter with Built-In Crystal Calibrator—A. A. Jones. (*R.S.G.B. Bull.*, vol. 22, pp. 18–19; August, 1946.) A calibrated variable-frequency oscillator feeds a mixer stage followed by an audio-frequency amplifier. The variable-frequency oscillator has ranges 125 to 250 kilocycles and 1 to 2 megacycles enabling frequencies in the range 125 kilocycles to 20 megacycles to be measured by heterodyning the signal of unknown frequency against harmonics of the variable-frequency oscillator. A 1-megacycle crystal oscillator gives selected check points at which the frequency calibration of the variable-frequency oscil-

lator can be corrected by a trimming capacitor. Reading accuracy 1 part in 5000.

621.317.761:621.396.712 **2975**

Measuring and Monitoring Broadcast Frequencies—L. S. Cole. (*Electronics*, vol. 19, pp. 110–111; July, 1946.) A harmonic of a multivibrator controlled by a signal received from the monitored station is beat against the signal from a standard-frequency transmission, and the frequency of the beat note is measured. The circuit of the multivibrator unit is given.

621.317.761.029.4 **2976**

Electronic Frequency Meter for L.F.—W. A. Roberts. (*Electronic Eng.*, vol. 18, pp. 238–240; August, 1946.) The signal of unknown frequency is applied to two high-gain-pentode limiting stages, giving substantially square-wave output. Pulses obtained by differentiating are applied to a tube held at cut-off. The resulting anode current varies linearly with the frequency of the pulses, and a meter in the anode circuit is directly calibrated in frequency. Ranges, 0 to 2 kilocycles, 0 to 4 kilocycles, and 0 to 8 kilocycles; the reading is substantially independent of signal waveform and amplitude. Circuit details are given.

621.317.79:621.315.21.029.6 **2977**

Measurement of Velocity of Propagation in Cable—B. Kramer and F. Stolte. (*Electronics*, vol. 19, pp. 128–129; July, 1946.) A variable-frequency oscillator (95 to 105 megacycles) is loosely coupled to a parallel-tuned circuit in parallel with a tube voltmeter. The tuning of the oscillator is ganged with that of the coupled circuit so that the circuit resonates with the oscillator at all frequencies. A sample of cable of fixed length (150 centimeters for polythene dielectric) known to be $\frac{3}{4}$-wavelength at about 100 megacycles is connected in series with the coupled circuit, throwing the circuit off tune with the oscillator except at the frequency at which the cable is $\frac{3}{4}$-wavelength long. The tuning is adjusted until the voltmeter gives a maximum reading, and the mean velocity in the cable, deduced from $v=\lambda f$, is read from the directly calibrated tuning control. Estimated accuracy, 2 per cent.

621.317.79:621.395.82:621.395.645 **2978**

Intermodulation Testing [of Audio-Frequency Amplifiers]—J. K. Hilliard. (*Electronics*, vol. 19, pp. 123–127; July, 1946.) The principle of the method is the same as that given in 2641 of September (Pickering). The equipment is described with block diagrams. The results of tests on typical amplifiers are shown by graphs which illustrate the reduction of intermodulation with various improvements of amplifier design.

621.317.79:621.396.619 **2979**

A Percent [Amplitude] Modulation Meter—R. P. Turner. (*Radio News*, vol. 35, pp. 43, 121; May, 1946.) Constructional details of a direct-reading alternating-current mains-operated instrument.

621.317.79:621.397.62 **2980**

A Television Signal Generator: Part 3—R.F. Circuits and Monitors—R. G. Hibberd. (*Electronic Eng.*, vol. 18, pp. 251–253; August, 1946.) Detailed circuit of 45-megacycle vision generator. The signal from a 7.5-megacycle crystal oscillator is frequency-multiplied to 45 megacycles and link-coupled to a push-pull suppressor-grid-modulated output stage. Five output sockets are provided, suitably isolated and matched to 100-ohm cable, and a monitor stage is incorporated in the output. A similar unit is used for the sound channel. Picture and waveform monitors are described for checking output quality and for rapid fault location. Conclusion of series; for previous parts see 2255 of August and 2646 of September.

621.318.5.083 **2981**

Induction Relay Testing—C. G. Rumsam. (*Elec. Rev.* (London), vol. 138, pp. 841–843; May 31, 1946.) Necessity for suitable precautions in test equipment when accurate timing checks of the relay are required.

621.385.3:621.396.822 **2982**

Fluctuations in Electrometer Triode Circuits—van der Ziel (*See* 2833.)

621.396.91:551.51.053.5 **2983**

Ionosphere Measuring Equipment—P. G. Sulzer. (*Electronics*, vol. 19, pp. 137–141; July, 1946.) Description, with circuit diagrams, of an equipment that sweeps the range 1 to 20 megacycles in 30 seconds. The transmitted frequency is obtained as the beat between a 30-megacycle pulsed oscillator and a variable 31- to 50-megacycle oscillator. The difference-frequency signal is amplified by an untuned wideband amplifier. The returning signal is beat with the 31- to 50-megacycle signal to give 30 megacycles before passing to a sensitive receiver.

621.317 **2984**

Alternating Current Measurements at Audio and Radio Frequencies. [Book Review]—D. Owen. Methuen, London, second edition, 120 pp., 5s. (*Wireless Eng.*, vol. 23, p. 233; August, 1946.)

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

537.228.1:612.087 **2985**

A Piezo-Electric Unit for General Physiological Recording—J. L. Malcolm. (*Jour. Sci. Instr.*, vol. 23, pp. 146–148; July, 1946.) Uses *X*- or *AT*-cut quartz crystal.

537.591:[621.317.39.083.7+621.396.9 **2986**

New Cosmic Ray Radiosonde Techniques—S. A. Korff and B. Hamermesh. (*Jour. Frank. Inst.*, vol. 241, pp. 355–368; May, 1946.) The measuring instrument, weighing 119 pounds, is raised by a cluster of seventy balloons. It consists of a neutron counter (ionization chamber) with three shields which are placed over the counter in sequence. Impulses from the counter are made to cause momentary cessation of a 2000-cycle note modulating a very-high-frequency transmitter of conventional design. Barometric indications of balloon height, and the beginning of each cycle of shield changes, are signaled by coded interruptions of the modulation. The ground equipment comprises a standard receiver and pen recorder. The equipment and the flight technique are described. For previous work see 29 of 1942 (Clarke and Korff).

539.16.08:614.84 **2987**

Electronic Fire and Flame Detector—P. B. Weisz. (*Electronics*, vol. 19, pp. 106–109; July, 1946.) Detects flames, sparks, and arcs by the use of a Geiger-Müller counter tube sensitive to ultraviolet light of wavelength shorter than 3000 angstroms. The device is not sensitive to daylight or to light from glass-enclosed sources. The tube and associated circuits are described. The device is triggered, e.g., by a match struck 60 feet away.

551.501+621.396.91+621.317.39.083.7 **2988**

Recent Advances in Meteorological Methods—N. K. Johnson. (*Nature*, (London), vol. 157, pp. 247–250; March 2, 1946.) Early developments included the German radio buoy, and the determination of the position of storms by atmospherics. Upper winds are measured by means of balloons, carrying radio transmitters to enable their track to be plotted by direction-finding technique, or carrying only reflectors for detection by radar. Radiosonde balloons are used to obtain information on the temperature, pressure and humidity of the upper air. Reference is also made to observations taken in aircraft, and to the use of high-velocity shells for exploration of the stratosphere.

578.088.7:621.317.755 **2989**

Double-Beam C.R. Tube in Biological Research—Bullock. (*See* 3072.)

621.317.39:620.172.222 **2990**

Electric Strain Gauges—A. B. White. (*Elec. Rev.* (London), vol. 139, pp. 175–176; August 2, 1946.) Description of the principles of operation of the resistance strain gauge. Use of cathode-ray tube technique for recording varying strains is outlined.

621.317.39:621.753.3 **2991**

Electronic Comparator Gage—W. H. Hayman. (*Electronics*, vol. 19, pp. 134–136; July, 1946.) Description, with circuit diagrams, of a device for converting the movement of the contact point of a mechanical gauge into a change of inductance in a radio-frequency circuit, giving an electrical indication. At its most sensitive setting the device gives readings to about 10^{-6} inch. Relays can be operated when measurements fall outside prescribed limits.

621.365[.5+.92 **2992**

Radio-Frequency Heating—L. Hartshorn. (*Nature*, (London), vol. 157, pp. 607–610; May 11, 1946.) Substance of Royal Institution lecture. A nontechnical description of the underlying principles of dielectric and induction hearing, and some examples of their applications.

621.365.5 **2993**

Induction Heating of Long Cylindrical Charges—H. F. Storm. (*Trans. A.I.E.E.* (*Elec. Eng.*, June, 1946), vol. 65, pp. 369–377; June, 1946.) Further development of formulas deduced in previous paper (981 of 1945) to include any radius of charge, and any depth of penetration, the generated heat being expressed in terms of a rapidly converging series. The analysis is applied to the case where the charge is subdivided into a number of cylindrical rods, and the optimum radius of rod for maximum inductor efficiency is deduced.

621.365.92 **2994**

Problems in the Design of High-Frequency Heating Equipment—W. M. Roberds. (Proc. I.R.E. and Waves and Electrons, vol. 34, pp. 489–500; July, 1946.) Discussion of the required coupling circuits. A simple analysis of a transformer-coupled circuit is given, and the advantages of close and loose coupling compared. A generator can be made more versatile if low-impedance tank circuits and loose coupling are employed.

621.38:518.5 **2995**

Super Electronic Computing Machine—A. W. Burke. (*Elec. Ind.*, vol. 5, pp. 62–67, 96; July, 1946.) A description of the electronic numerical integrator and computer (Eniac) with diagrams of some of the circuits. See also 1928 of July.

621.38:665.54 **2996**

Electronic Uses in Petroleum Refining—(*Elec. Ind.*, vol. 5, pp. 58, 106; July, 1946.) Electronic devices prove useful in catalytic petroleum processes where rapid and accurate means of following changes in complex chemical mixtures are necessary.

621.384 **2997**

Application of Pulse Technique to the Acceleration of Elementary Particles—E. G. Bowen, O. O. Pulley, and J. S. Gooden. (*Nature*, (London), vol. 157, p. 840; June 22, 1946.) May provide a cheap tool for studies in nuclear physics.

621.385.833+537.533.72 **2998**

Optical Characteristics of a Two-Cylinder Electrostatic Lens—L. S. Goddard. (*Proc. Camb. Phil. Soc.*, vol. 42, part 2, pp. 106–126; June, 1946.) "Explicit formulas are obtained for the focal lengths and the positions of the principal planes. These formulas involve the two parameters which completely specify the lens, namely, the voltage ratio σ and the gap with ϵ (the separation of the cylinders) . . . Use of the method in conjunction with the relaxation method for determining electrostatic field distributions means that electrostatic electron optical systems of axial symmetry may be designed to a large extent in the office instead of in the laboratory."

621.385.833+537.533.72 **2999**

A Note on the Petzval Field Curvature in Electron-Optical Systems—L. S. Goddard. (*Proc. Camb. Phil. Soc.*, vol. 42, part 2, pp. 127–131; June, 1946.) The work of Glaser (2205 of 1941) is applied to obtain exact expressions for the Petzval field curvature in the case of both magnetic and electrostatic electron lenses. See also Klemperer and Wright (2483 of 1939) for similar work on a two-cylinder electrostatic lens.

778:537.533.8:621.386.1 **3000**

Secondary Electron Photography—J. E. Roberts. (*Nature*, (London), vol. 157, pp. 695–696; May 25, 1946.) Irradiation of printed matter with high-voltage X-rays gives a positive image due to secondary emission of electrons from metallic ink particles.

621.38:6 **3001**

Electronics in Industry. [Book Review]—G. M. Chute. McGraw-Hill Book Co., New York, 1946, 461 pp., $5.00. (*Elec. Ind.*, vol. 5, p. 112; August, 1946.) ". . . prepared for instrumentation men and operating technicians in industry. . . . "

PROPAGATION OF WAVES

07(94):621.396.11 **3002**

Radio Propagation Bulletin: Council for Scientific and Industrial Research—(*Jour. Inst. Eng.* (Australia), vol. 18, p. 61; March, 1946.) Notice of new Australian publication.

551.51.053.5:523.78"1945.07.09":621.396.11 **3003**

On the Results of Radio-Observations During the Solar Eclipse (Corpuscular and Ultra-Violet) of July 9, 1945—Al'pert and Gorozhankin. (*See* 2893.)

551.51.053.5:523.78 **3004**

Solar Eclipses and Radio Investigations of the Ionosphere—Al'pert and Gorozhankin (*See* 2892.)

551.51.053.5:621.396.11 **3005**

Ionosphere Storm Effects in the *E* Layer—Bennington. (*See* 2899.)

551.51.053.5:621.396.11 **3006**

On the Refractive Index of an Ionized Gas (Ionosphere)—Ginsburg. (*See* 2901.)

551.51.053.5:621.396.11 **3007**

Absorption of Radio Waves in the Ionosphere—Ya. L. Al'pert and V. L. Ginsburg. (*Bull. Acad. Sci.* (U.R.S.S.), sér. phys., vol. 8, no. 2, pp. 42–67; 1944. In Russian.) Complete paper, of which an English summary was abstracted in 2514 of 1945.

621.396.11+621.392 **3008**

Propagation of Electromagnetic Waves Along a Single Wire—V. V. Valdimirski. (*Bull. Acad. Sci.* (U.R.S.S.), sér. phys., vol. 8, no. 3, pp. 139–149; 1944. In Russian.) Complete paper, of which an English summary was abstracted in 2533 of 1945.

621.396.11 **3009**

On a Certain Method of Solving Problems of Propagation of Electromagnetic Waves Along the Surface of the Earth—M. Leontovich. (*Bull. Acad. Sci.* (U.R.S.S.), sér. phys., vol. 8, no. 1, pp. 16–22; 1944. In Russian.) Complete paper, of which an English summary was abstracted in 2532 of 1945.

621.396.11 **3010**

The Propagation of Radio Waves Along a Real Surface—E. L. Feinberg. (*Bull. Acad. Sci.* (U.R.S.S.), sér. phys., vol. 8, no. 3, pp. 109–131; 1944. In Russian.) For an English version see 2529 of 1945. (In the second line of 2529 of 1945 "homogeneous" should read "inhomogeneous.")

621.396.11 **3011**

On the Effective Path of Radio Waves Along the Ground—E. L. Feinberg. (*Bull. Acad. Sci.* (U.R.S.S.), sér. phys., vol. 8, no. 3, pp. 132–138; 1944. In Russian.) For English version see 1962 of July.

621.396.11 **3012**

On the Theory of the Propagation of Radio Waves Along a Real Surface—E. L. Feinberg. (*Bull. Acad. Sci.* (U.R.S.S.), sér. phys., vol. 8, no. 4, pp. 200–209; 1944. In Russian.) Complete paper, of which an English summary was abstracted in 2531 of 1945.

621.396.11:551.5 **3013**

Radio Meteorology: Influence of the Atmosphere on the Propagation of Ultra-Short Radio Waves—(*Nature*, (London), vol. 157, pp. 860–862; June 29, 1946.) Summary of the proceedings of a joint conference of the Royal Meteorological Society and the Physical Society.

Appleton quoted instances of radar ranges beyond the geometrical horizon and showed that radio vision around the earth is possible when the lapse rate of atmospheric refractive index is greater than 0.15×10^{-6} per meter. The most favorable combination for producing such an atmosphere is a temperature inversion associated with a lapse of water vapor pressure.

Sheppard "discussed the physical processes determining the vertical gradients of temperature and humidity in the bottom kilometer of the atmosphere."

Smith-Rose stated that there were indications that a simple theory was adequate to explain the observed fields of 9-centimeter and 3-centimeter waves over land and sea except for low-level links, and Booker discussed the duct process at these low levels.

Ryde stated that attenuation and back-scattering of centimeter waves ($\lambda>2$ centimeter) due to water droplets (diameter d of order 10μ) is proportional to d^3. For drizzle and rain scattering follows Rayleigh's law $[\alpha(d-\lambda)^4]$. Attenuations of 3-centimeter waves up to 1 decibel per kilometer in Britain and 6 decibels per kilometer in the tropics are deduced. See also 1972 (Robertson and King) and 1973 (Mueller) of July.

621.396.11:551.51.053.5 **3014**

Maximum Values of Radio Field Intensity on Vertical Reflection from the Ionosphere, and an Evaluation of the Coefficient of Reflection—V. N. Kessenikh. (*Bull. Acad. Sci.* (U.R.S.S.), sér. phys., vol. 8, no. 2, pp. 68–75; 1944. In Russian.) Complete paper, of which an English summary was abstracted in 2522 of 1945.

621.396.11:551.51.053.5:523.746 **3015**

Sunspots and Radio Communication—(*Jour. Frank. Inst.*, vol. 241, no. 5, pp. 369–371; May, 1946.) The occurrence between January 29, and February 11, 1946, of one of the largest sunspot groups ever recorded was the cause of severe disturbances to radio propagation. Bright eruptions associated with the group gave rise to a number of sudden "fade-outs" varying in length from a few minutes to several hours. These are believed to be due to increased ionization in the *D* region of the ionosphere with resulting increase in absorption. The central meridian passage of the main spot was followed 24 hours later by severe magnetic and ionospheric storms associated with auroral displays. High-frequency radio communication, particularly across the North Atlantic, was considerably interfered with due to depression of F_2 layer critical frequencies and increased absorption.

621.396.11:551.51.053.5"1946.07" **3016**
Short-Wave Conditions: Expectations for July—T. W. Bennington. (*Wireless World*, vol. 52, p. 222; July, 1946.)

621.396.11.029.63/.64 **3017**
Propagation of Short Radio Waves—E. C. S. Magar. (*S. Afr. Eng.*, vol. 57, p. 131; June, 1946.) Extracts from a paper read at the radiolocation convention of the Institution of Electrical Engineers. For other accounts see 2576 of September and back reference.

621.396.67 **3018**
The Radiation Field of an Unbalenced Dipole—Kelvin. (*See* 2822.)

RECEPTION

621.394/397].822+621.392.6 **3019**
Suppression of Spontaneous Fluctuations in Amplifiers and Receivers for Electrical Communication and for Measuring Devices—Strutt and van der Ziel. (*See* 2843.)

621.394/.397].822+621.392.6 **3020**
Suppression of Spontaneous Fluctuations in 2*n*-Terminal Amplifiers and Networks—van der Ziel and Strutt. (*See* 2844.)

621.394/.397].822 **3021**
Fluctuations of Electric Current—D. A. Bell. (*Jour. I.E.E.* (London), part I, vol. 93, p. 275; June, 1946.) Long abstract of 1038 of April.

621.396.61/.62 **3022**
"Portarig" Ham Station—Scott. (*See* 3098.)

621.396.61/.62].029.5:629.135 **3023**
A General-Purpose Radio-Communication Equipment for Military Aircraft—W. W. Honnor and J. P. Blom. (*A.W.A. Tech. Rev.*, vol. 6, pp. 505–518; March, 1946.) Provides for transmission over frequency ranges 140 to 500 kilocycles and 2 to 20 megacycles with crystal control over parts of the high-frequency range, and reception over the whole range 140 to 20,000 kilocycles. Operation on continuous wave, modulated continuous wave, and telephony is provided for, and direction-finding and homing systems are incorporated. For more details of the receiver see 3032 below.

621.396.615:621.396.662 **3024**
Permeability-Tuned Oscillators—Hunter. (*See* 3103.)

621.396.619 **3025**
F.M.-A.M. Conversion at U.H.F.—W. van Roberts. (*Elec. Ind.*, vol. 5, p. 82; July, 1946.) The frequency-modulation signal is passed through a wave guide slightly above the cut-off diameter. The attenuation in the pipe increases rapidly with increase in frequency, so that the emerging wave is amplitude-modulated. Summary of United States patent 2,393,414.

621.396.621+534.43 **3026**
A New Radiogramophone—Svenskradio 1467—C. Fredin (*Ericsson Rev.*, vol. 23, no. 1, pp. 44–47; 1946.) Specification and circuit diagram.

621.396.621 **3027**
Radio Data Sheet 336. (*Radio Craft*, vol. 17, p. 615; June, 1946.) Data for Belmont radio model 6D111, series A.

621.396.621 **3028**
Sobell Type 615 [Broadcast Receiver]—(*Wireless World*, vol. 52, pp. 226–227; July, 1946.) Test report and circuit diagram.

621.396.621 **3029**
Ex-R.A.F. Communication Receiver—"Ex-Signals." (*Wireless World*, vol. 52, pp. 212–216; July, 1946.) Description of Royal Air Force receiver type R.1155, with practical details for converting it to civilian needs, including elimination of direction-finding circuit, construction of a power pack, and provision for loudspeaker operation. Circuit diagrams and component values of the receiver are included.

621.396.621 **3030**
An Amateur-Band Eight-Tube Receiver—B. Goodman. (*QST*, vol. 30, pp. 13–18; August, 1946.) Constructional details of a communication-type receiver with frequency ranges limited to the amateur bands.

621.396.621:621.396.828 **3031**
[Methods of] Reducing Hum Levels [in Mains Receivers]—J. King. (*Radio Craft*, vol. 17, pp. 619, 648; June, 1946.)

621.396.621.029.5:629.135 **3032**
A General-Purpose Communication Receiver for Military Aircraft—J. B. Rudd and T. R. W. Bushby. (*A.W.A. Tech. Rev.*, vol. 6, pp. 519–527; March, 1946.) A more detailed description of the receiver section of the equipment described in 3023 above, with a schematic diagram.

621.396.621.029.5:629.135 **3033**
A Ten-Channel Aircraft Receiver—J. B. Rudd. (*A.W.A. Tech. Rev.*, vol. 6, pp. 489–504; March, 1946.) A superheterodyne for either local or remote control on any one of ten crystal-controlled frequencies from 200 to 13,000 kilocycles. Alternatively a manually tuned range covers 200 to 400 kilocycles. A cathode-follower input circuit is used, and the beat oscillator may be remotely controlled.

621.396.621.029[.58+.62 **3034**
F.M. and A.M. Receiver for Comparison Tests—W. F. Frankart. (*Electronics*, vol. 19, p. 168; July, 1946.) Brief description and circuit diagram. Tuning range 15 to 170 megacycles, sensitivity 2 microvolts. The performance was improved by the use of germanium-crystal diodes.

621.396.622 **3035**
Applying A.M.D. [Audio-Modulated Detection] to the Communications Receiver—D. A. Griffin and L. C. Waller. (*QST*, vol. 30, pp. 56–61, 136; August, 1946.) Constructional details of an adapter for a communication receiver comprising an audio oscillator, squaring amplifier, selective amplifier, and a power supply. For a discussion of the merits of the system see 2694 of September (same authors).

621.396.622.72 **3036**
Oscillation Hysteresis in Grid Detectors—Zepler. (*See* 2854.)

621.396.682:621.396.621 **3037**
A.C./D.C. Voltage Dropping—W.T.C. (*Wireless World*, vol. 52, pp. 236–237; July, 1946.) The use of a series resistor for reducing the mains voltage applied to an alternating-current or direct-current series-heater receiver is unsatisfactory with alternating-current mains. The rectifier conducts only at the peaks of the positive half-cycles and causes additional voltage drop at those periods. Adjustment of the dropping resistor to give correct effective heater current, therefore, gives too low a voltage for the high-voltage supply. Two alternative schemes for overcoming this difficulty are suggested.

621.396.82:551.57:629.135 **3038**
Plight Research on Precipitation Static—E. L. Cleveland. (*Elec. Ind.*, vol. 5, pp. 66–69, 94; August, 1946.) A general account of the causes, effects, and remedies. See also 1991, 1992, 1993 of July and 2322, 2323, and 2344 of August (United States Army-Navy precipitation-static project).

621.397.823 **3039**
Tele[vision] Interference: Parts 1 and 2—Goldsmith. (*See* 3097.)

621.396/.397].62 **3040**
Radio Receiver Design. Part 2: Audio-Frequency Amplifiers, Television and Frequency-Modulated Receiver Design. [Book Review]—K. R. Sturley. Chapman and Hall, London, 1945, 480 pp., 28s. (*Nature*, (London), vol. 157, p. 751; June 8, 1946.) This volume, with its companion Part 1, "forms a most useful work of reference for the radio engineer and designer." For other reviews, see 414 of February and 728 of March.

STATION AND COMMUNICATION SYSTEMS

621.394/.396]"1846/1946" **3041**
Developments in Teletechnics 1846–1946: Tele-Signalling—T. Ericsson. (*Ericsson Rev.*, vol. 23, no. 2, pp. 150–160; 1946.)

621.394/.395]"1846/1946" **3042**
Developments in Teletechnics 1846–1946: Telegraphy and Telephony—N. Heden (*Ericsson Rev.*, vol. 23, no. 2, pp. 122–149; 1946.) Survey from Swedish firm of L. M. Ericsson.

621.395.44:[621.315.052.63+621.398 **3043**
New Carrier-Frequency Systems for Telephony and Remote Metering and Control on Power Lines—S. Rhode. (*Ericsson Rev.*, vol. 23, no. 1, pp. 2–34; 1946.) A discussion of the fundamentals of carrier-frequency transmission over power lines leading up to a description of the Ericsson equipment giving telephone, teleprinter, remote metering, and control-signal facilities.

Single-sideband working is used with

carrier frequencies in the band 50 to 150 kilocycles; different frequencies are used for receiving and transmitting telephony, and for the remote metering and control channels. The modulation and demodulation processes involved are explained. The terminal equipment protective devices, and auxiliary equipment are described.

A telephone-channel range of 300 to 400 kilometers on a 220-kilovolt line is obtained without repeaters.

621.395.44 3044

Three-Channel Carrier Telephone System for Open-Wire Lines—T. Bohlin. (*Ericsson Rev.*, vol. 23, no. 1a, pp. 50–70; 1946.) A detailed description of a modern system for carrier-telephone communications. For distances up to 500 kilometers only terminal equipment is required, but for long distances up to several thousand kilometers intermediate repeaters are inserted. Each channel uses a frequency band of 300 to 2700 cycles and transmission and reception occupy the whole range from 6 kilocycles to 30 kilocycles, different frequencies being used in different directions. Attenuation curves are given, and the effect of wet and dry weather indicated.

621.395.64 3045

Rural Line Repeater with Negative Feedback—J. Ljungberg. (*Ericsson Rev.*, vol. 23, no. 1a, pp. 71–74; 1946.) The equipment consists of 2-wire repeaters which can be connected to the mains, and is suitable for use where a normal repeater station is not warranted.

621.395.823 3046

Practical Aspects of Telephone Interference Arising from Power Systems—P. B. Frost and E. F. H. Gould. (*Jour. I.E.E.* (London), part I, vol. 93, pp. 255–274; June, 1946.) Experimental paper divided into six sections: (1) electromagnetic induction at fundamental frequency; good agreement between calculated and measured values of induced voltage usually obtains; (2) interference at audio frequencies, mainly from faulty power lines due to induction of harmonic components; (3) multiple earthing of high-voltage systems; (4) multiple earthing of low-voltage systems; (5) apparatus developments: gas-discharge tubes, noise-eliminating filters, improved psophometer; and (6) rise of earth potential, damage produced near faults in power systems.

621.396"1846/1946" 3047

Developments in Teletechnics 1846–1946:Radio-Technics—T. Overgaard. (*Ericsson Rev.*, vol. 23, no. 2, pp. 161–174; 1946.) Survey from Swedish firm of L. M. Ericsson.

621.396.13 3048

A Preview of the Western Union System of Radio Beam Telegraphy: Part 1—J. Z. Millar. (*Jour. Frank. Inst.*, vol. 241, pp. 397–413; June, 1946.) Includes a history of the electric telegraph, with brief descriptions of the teleprinter, multiplex, and facsimile equipment, and of carrier telegraphy using frequency modulation for wire-line operation. A general description is given of the projected system of radio-beam telegraphy which will eventually replace all line telegraph facilities and provide channels for relaying television. The experimental equipment at present in use operates at 4000 megacycles and microwave techniques developed in the last few years are incorporated. Propagation tests in four frequency bands are also being carried out.

621.396.13:621.396.97 3049

Multiplex Broadcasting—D. D. Grieg. (*Elec. Commun.*, vol. 23, pp. 19–26; March, 1946.) Proposals for broadcasting multiple programs over the widest area by means of a ultra-high-frequency relay network using a multiplex system. The system offers great economy of relay equipment. Methods of multiplexing are reviewed, and pulse-time methods are shown to be preferable.

621.396.6.029.58 3050

Practical Break-In Operation—W. H. Allen. (*R.S.G.B. Bull.*, vol. 22, pp. 7–9; July, 1946.) Intervals in transmission may be used for replies or repetition requests from the receiving end. Practical requirements and circuits are described.

621.396.61.029.64 3051

Our Best DX—800 Feet!—A. H. Sharbaugh and R. L. Watters. (*QST*, vol. 30, pp. 19–22, 24; August, 1946.) Description of apparatus used to obtain two-way telephone communication over a range of 800 feet at a frequency of 21,900 megacycles. Transmitter and receiver used the same oscillator, a General Electric *Z*-668 reflex velocity-modulated tube. The power radiated was less than 10 milliwatts.

621.396.619.018.41 3052

Frequency Modulation—T. J. Weijers. (*Philips Tech. Rev.*, vol. 8, pp. 42–50; February, 1946.) General description of methods of modulating radio-frequency waves, with a detailed treatment of frequency modulation. The main characteristics necessary for frequency-modulation transmitters and receivers are discussed, and a section is added on nonquasi-stationary phenomena in networks.

621.396.619.16 3053

Pulse-Time Modulation—J. Zwislocki-Moscicki. (*Elec. Ind.*, vol. 5, p. 80; July, 1946.) Illustrated summary of a paper in *Bull. Schweiz. Elektrotech. Ver.*, July 25, and August 22, 1945. A frequency-modulated beat note of about 50 kilocycles is obtained between a steady oscillation and a frequency-modulated oscillation of about 1 megacycle. The beat signal is formed into pulses and used to key a high-frequency (in this case 30-megacycle) transmitter. In the receiver, the pulses control the frequency of a dynatron square-wave generator from which a signal is passed to a discriminator. Calculations of the effect of a disturbing signal are given in the original paper.

621.396.619.16 3054

Pulse Modulation—E. Fitch: E. R. Kretzmer. (*Wireless Eng.*, vol. 23, pp. 231–233; August, 1946.) Two letters discussing 183 of January (Roberts and Simmonds) and 1676 of June (Shepherd). Formulas more exact than those given in 183 are deduced for phase-modulated and duration-modulated pulses. See also 2707 of September (Roberts and Simmonds).

621.396.712.004.5 3055

Preventive Maintenance for Broadcast Stations: Part 2—C. H. Singer. (*Communications*, vol. 26, pp. 28, 55; July, 1946.) Discussion of the purpose, handling, and packing of maintenance tools, including wrenches, drills, etc. For part 1 see 2709 of September. To be continued.

621.397+534.862 3056

S.M.P.E. [Society of Motion Picture Engineers] Spring Technical Conference [New York, May, 1946].—(*See* 3087.)

629.135:621.396.82:551.57 3057

Flight Research on Precipitation Static—Cleveland. (*See* 3038.)

SUBSIDIARY APPARATUS

537.531 3058

A Simple X-Ray Spectrometer—R. S. Rivling and H. P. Rooksby. (*Jour. Sci. Instr.*, vol. 23, pp. 148–150; July, 1946.) Built of Meccano parts and sufficiently accurate for the determination of crystal axes.

551.57:518.3 3059

Measurement of Atmospheric Humidity—E. C. Woods. (*Distrib. Elec.*, vol. 19, pp. 152–153; July, 1946.) A nomogram for the direct indication of relative humidity from wet and dry bulb temperatures.

621–712 3060

Low Temperatures at Low Cost—H. N. Brown. (*Jour. Frank. Inst.*, vol. 240 pp. 487–495; December, 1945.) Design details of a temperature test chamber for small electronic components. Preheated to 100 degrees centigrade, it is cooled steadily at 2/3 degree centigrade per minute to −60 degrees centigrade by gases circulated over solid carbon dioxide. Means of controlling the cooling rate are described, and introduction of moisture is guarded against. Other applications of the equipment should be possible.

621.3.066.6:629.1-272 3061

Electrical Contact Springs—(*Jour. I.E.E.* (London), part III, vol. 93, p. 242; July, 1946). Discussion before the Institute of Electrical Engineers opened by L. B. Hunt and H. G. Taylor. For previous work see 2786 and 2787 of 1945.

621.314.2.017 3062

Thermal Characteristics of Transformers: Part 2—V. M. Montsinger. (*Gen. Elec. Rev.*, vol. 49, pp. 31–40; May, 1946.) Methods of calculating temperature rise in windings and in cooling media are applied to transformer problems. The effects of shape and surface color and of wind and altitude on heat dissipation are discussed. For part 1 see 2015 of July. To be continued.

621.314.2.029.5:621.396.619.018.41 3063

The Theory and Design of Intermediate-Frequency Transformers for Frequency-Modulated Signals—Ross. (*See* 2831.)

621.314.5 3064

Exciter-Regulator for Aircraft Alternators—F. T. Hadley, A. W. Forsberg and O. Krauer. (*Electronics*, vol. 19, pp. 120–122; July, 1946.) A description of a system of self-excitation of an alternating-current generator using an electronic exciter controlled by a voltage regulator. Circuit diagrams and performance are given for two equipments: a 3-phase constant-frequency main supply, and a single-phase variable-frequency auxiliary supply.

621.314.632.029.62:[546.28+546.289 3065
Crystal Rectifiers—Stephens. (*See* 3108.)

621.315.21.029.4/.6]:536.4 3066
The Power Rating (Thermal) of Radio-Frequency Cables—R. L. Mildner. (*Jour. I.E.E.* (London), part III, vol. 93, pp. 296–304; July, 1946.) "The principles used in calculating the temperature rise in cables which are required to transmit radio-frequency power are considered. The theoretical attenuation characteristics and power ratings of a number of standard radio-frequency cables are set down in graphical form for a wide range of operating frequencies. The ratings are based on a maximum temperature rise of 30 degrees centigrade, in an ambient of 55 degrees centigrade, established in a matched line for the steady-state condition. The use of suitable "rating factors" for other operating conditions is proposed. The effect of much operating conditions as the presence of standing waves and the effect of end cooling are briefly considered in relation to the rating of the cables."

621.315.668.2 3067
Steel Towers for Transmission Lines—P. J. Ryle. (*Nature*, (London), vol. 157, p. 881; June 29, 1946.) Formula for above-ground weight in terms of overall height and overturning moment. Summary of an Institution of Electrical Engineers paper.

621.316.578.1 3068
Variable Timing up to Thirty Seconds—D. G. Haines. (*Electronics*, vol. 19, pp. 154–158; July, 1946.) Short description, with circuit diagram, of an equipment primarily for controlling photographic exposures. Minimum time 0.5 second.

621.316.722.078.3 3069
Voltage Stabilization—W. Easton. (*Elec. Rev.*, (London), vol. 138, pp. 1003–1015; June 28, 1946.) A stabilizer is described giving a stability of better than 1 in 1000 when connected to a 440-volt 3-phase direct-current supply subject to a 12 per cent variation of voltage.

621.316.74:621.396.611.21 3070
Oven for Airborne Piezoelectric Crystals—S. Eaton. (*Elec. Commun.*, vol. 23, p. 41; March, 1946.) A small unit on a standard 11-pin base for maintaining crystals at a temperature of 75 ±1 degrees centigrade over the range of ambient temperature −40 degrees to +70 degrees centigrade, with a variation of less than 0.3 degree centigrade for a constant ambient temperature.

621.317 3071
Exhibition of British Scientific Instruments in Sweden—(*Jour. Sci. Instr.*, vol. 23, pp. 137–138; July, 1946.)

621.317.755:578.088.7 3072
Double-Beam C.R. Tube in Biological Research—T. H. Bullock. (*Electronics*, vol. 19, pp. 103–105; July, 1946.) Instructions for modifying the DuMont 247 oscilloscope to take the 5SP double-beam tube, with an account of some of the resulting facilities.

621.317.755.087.5:620.172.222 3073
A Six-Channel Electronic Recorder—M. Scott. (*Electronic Eng.*, vol. 18, pp. 233–235, 261; August, 1946.) Description of a 6-cathode-ray-tube oscillograph giving simultaneous records photographed by a single camera unit on 120-millimeter paper moving at 0.5 to 1000 inches per second. Each tube has an alternating-current-direct-current amplifier (0 to 10 kilocycles), monitor tube, and a calibration and time marking unit controlled by a 1-kilocycle fork oscillator. Primarily designed for strain-gauge bridge measurements; built-in balancing units allow 48 channels to be switched in batches of 6 without rebalancing the bridge.

621.385.833 3074
Electron Microscope of the State Optical Institute—W. N. Werzner. (*Bull. Acad. Sci.* (U.R.S.S.), sér. phys., vol. 8, no. 5, pp. 232–234; 1944. In Russian.) Description of the microscope and its lenses, with examples of the magnification produced. See also 2302 of 1945. English summary noted in 1948 of July.

621.386.1 3075
X-Ray Tubes with Rotating Anode ("Rotalix" Tubes)—J. A. van der Tuuk. (*Philips Tech. Rev.*, vol. 8, pp. 33–41; February, 1946.) The latest tubes are described, and various problems connected with the rotating anode are discussed.

621.395.625.6:621.383 3076
A Phototube for Dye Image [Colour Film] Sound Track—A. M. Glover and A. R. Moore. (*Jour. Soc. Mot. Pict. Eng.*, vol. 46, pp. 379–386; May, 1946.)

621.395.625.6:621.383 3077
Behavior of a New Blue-Sensitive Phototube [for Black-and-White or Colour Film Tracks] in Theater Sound Equipment—Phyfe. (*See* 2806.)

621.396.62+621.317.35 3078
Alarm System for Panoramic Receivers—W. A. Anderson (*Electronics*, vol. 19, pp. 92–95; July, 1946.) A motor-driven commutator divides each sweep period of the panoramic display into 40 equal parts and supplies a direct voltage with an independently controlled amplitude during each part. The output from this device is added to the receiver output and adjusted to cancel the cathode-ray deflections produced by the received signals. Deflections produced by reception of a new signal or by drift of the frequency of a signal previously neutralized triggers an alarm circuit. Other applications of the device (e.g., for coded transmission and network analysis) are mentioned.

621.396.682.029.4/.6 3079
R. F. Power Supplies—M. Rhita. (*Radio Craft*, vol. 17, pp. 616, 647; June, 1946.) A 300-kilocycle oscillator with an air-cored transformer and rectifier produces 10 kilovolts for cathode-ray tube operation.

771.35 3080
A Classification of Photographic Lens Types—R. Kingslake. (*Jour. Opt. Soc. Amer.*, vol. 36, pp. 251–255; May, 1946.) The classification, based on the number of components in the lens, has been used in the Eastman Kodak Company for several years.

539.16.08+621.318.572 3081
Electron and Nuclear Counters. [Book Review]—S. A. Korff. D. Van Nostrand, New York, 212 pp., $3.00. (*Elec. Ind.*, vol. 5, p. 112; July, 1946.) Deals with the action and construction of counter tubes and auxiliary electronic circuits. "... an extensive and scholarly summary...."

621.327.3/.4 3082
Electric Discharge Lumps. [Book Review]—H. Cotton. Chapman and Hall, London, 435 pp., 216 figures, 36s. (*Elec. Rev.*, (London), vol. 139, p. 26; July 5, 1946.) "... gives a most valuable account of the whole subject...."

TELEVISION AND PHOTOTELEGRAPHY

621.32:621.397.5 3083
An Appraisal of Illuminants for Television Studio Lighting—R. E. Farnham. (*Jour. Soc. Mot. Pict. Eng.*, vol. 46, pp. 431–440; June, 1946.) Discussion of required spectral sensitivity and illumination levels, and description of suitable sources.

621.325:621.397.5 3084
Carbon Arcs for Motion Picture and Television Studio Lighting—F. T. Bowditch, M. R. Null, and R. J. Zavesky. (*Jour. Soc. Mot. Pict. Eng.* vol. 46, pp. 441–453; June, 1946.) Discussion of photometric and spectral energy distribution of carbon arc sources and their future use in television.

621.383.8 3085
The Image Orthicon—A Sensitive Television Pickup Tube—A. Rose, P. K. Weimer, and H. B. Law. (PROC. I.R.E. AND WAVES AND ELECTRONS, vol. 34, pp. 424–432; July, 1946.) A detailed account of the tube described more briefly in 1376 of May. For application see 2374 of August (Kell and Sziklai).

621.396.615.17:621.397.645 3086
Electromagnetic Deflection: Television Line Scanning Amplifier—W. T. Cocking. (*Wireless World*, vol. 52, pp. 217–222; July, 1946.) Discussion of circuit technique using a pentode or tetrode tube, transformer-coupled to the deflector coil in a television line-scanning amplifier. Detailed analysis is given of the equivalent circuit of a typical amplifier. A linear scan may be obtained, using standard silicon-steel transformer cores, from a saw-toothed input which is rounded at the beginning and end of the fly-back, thus eliminating very high component frequencies. It is generally assumed that the circuit should be critically damped to avoid oscillations causing nonlinearity at the start of the scan, but by slightly underdamping, the effective capacitance across the primary circuit can be charged, by the oversewing, to the correct tube to suit the start of the scan. Details of a practical circuit and its adjustment for correct operation are given.

621.397+534.862 3087
S.M.P.E. [Society of Motion Picture

Engineers] Spring Technical Conference [New York, May 1946]—(*Electronics*, vol. 19, pp. 188, 198; July, 1946.) An account of the proceedings, including abstracts of the following papers: "Modernization Desired in Studio Equipment," by L. L. Ryder; "Theater Television," by L. B. Isaac, "Unified Approach to Film [Television] Pickup Tubes, and the Eye," by A. Rose; "Color Television," by P. C. Goldmark; "Factors Governing Frequency Response [in Film Sound Recording]," by M. Rettinger and K. Singer; and "Theater Servicing Test Equipment," by E. Stanko and P. V. Smith.

621.397:621.396.931 **3088**
Facsimile to Moving Train via V.H.F.—(*Electronics*, vol. 19, pp. 168, 178; July, 1946.) General description, with block diagrams.

621.397.26 **3089**
The B.B.C. Television Waveform—(*Jour. Telev. Soc.*, vol. 4, p. 196; December, 1945.) See also 2368 of August.

621.397.26 **3090**
Strato-Television—C. E. Nobles. (*Jour. Telev. Soc.* vol. 4, pp. 200–203; December, 1945.) An account of the Westinghouse proposals. See also 3970 of 1945 and 2370 of August.

621.397.26 **3091**
A Method of Transmitting Sound on the Vision Carrier of a Television System—D. I. Lawson, A. V. Lord, and S. R. Kharbanda (*Jour. I.E.E.* (London), part III, vol. 93, pp. 251–274; July, 1946.) "The paper describes a television system in which sound pulses having a constant height and variable width are inserted in the line synchronizing periods. It is claimed that this method of transmission leads to a simplified receiver and that the program quality is better in the presence of severe interference. Other advantages are that the frequency bandwidth for transmission is reduced; the method of receiving sound ensures automatic volume control; the sound pulses provide a fixed reference level for automatic volume control on the vision channel; mutual interference between vision and sound often present on two-channel reception is avoided; reduced transmission bandwidth simplifies the design of the receiving antenna; mutual coupling between the vision and sound antennas at the transmitter is avoided; and the installation and maintenance costs of the sound transmitter are saved.

"The frequency range of the system operated in conjunction with the pre-war British transmission would be limited to 5 kilocycles."

For earlier, less detailed accounts see 459 of February and back references. See also 1382 of May (Fredendall, Schlesinger and Schroeder).

621.397.5 **3092**
Studio Technique in Television—D. C. Birkinshaw and D. R. Campbell. (*Jour. I.E.E.* (London), part III, vol. 93, pp. 293–294; July, 1946.) Discussion of Institution of Electrical Engineers paper. See 3961 of 1945 and 781 of March.

621.397.5 **3093**
Informal Meeting [of the Television Society] and Exhibition—(*Jour. Telev. Soc.*, vol. 4, pp. 197–199; December, 1945.) Descriptions of some of the items exhibited.

621.397.6:621.396.67 **3094**
C.B.S. Tele Antenna—Sather. (*See* 2826.)

621.397.62:621.317.79 **3095**
A Television Signal Generator: Part 3—R. F. Circuits and Monitors—Hibberd. (*See* 2980.)

621.397.64 **3096**
[Frequency Compensation in] Video Amplification—J. McQuay. (*Radio Craft*, vol. 17, pp. 613, 655; June, 1946.)

621.397.823 **3097**
Tele[vision] Interference: Parts 1 and 2—T. T. Goldsmith. (*Elec. Ind.*, vol. 5, pp. 60–61, 108, and 73–75, 96; July and August, 1946.) A general analysis of signal sources which may affect both picture and sound reception quality, with (part 2) specific recommendations for engineering changes that can be made to effect improvement.

TRANSMISSION

621.396.61/.62 **3098**
"Portarig" Ham Station—R. F. Scott. (*Radio Craft*, vol. 17, pp. 611, 650; June, 1946.) A transmitter-receiver with crystal control for mains or 6-volt battery operation.

621.396.61 **3099**
Frequency Meters as Master Oscillators—E. H. Conklin. (*QST*, vol. 30, pp. 34, 132; August, 1946.) Description of an amplifier for boosting the output of a frequency meter (United States Service type) so that it may be used to control the frequency of a transmitter. The accuracy of frequency control was found to be about 100 cycles per megacycle under severe changes of temperature and humidity.

621.396.61/.62].029.5:629.135 **3100**
A General-Purpose Radio-Communication Equipment for Military Aircraft—Honnor and Blom. (*See* 3023.)

621.396.61.029.5:629.135 **3101**
A Communication Transmitter for Civil Aircraft—J. G. Downes. (*A.W.A. Tech. Rev.*, vol. 6, pp. 473–488; March, 1946.) The oscillator uses crystals for 2.5 to 13 megacycles and tuned circuits for 300 to 510 kilocycles. It drives a power amplifier (output 40 watts) which is anode-modulated by an audio amplifier to provide telephony, continuous-wave telegraphy and modulated continuous-wave telegraphy. Frequency selection is accomplished by means of a turret switch driven by an electric motor through gearing and a geneva movement.

621.396.615 **3102**
Raising the Efficiency of the V.H.F. Linear Oscillator—G. D. Perkins and H. G. Burnett. (*QST*, vol. 30, pp. 48–52; August, 1946.) A description of practical details for the frequency range 140 to 250 megacycles.

621.396.615:621.396.662 **3103**
Permeability-Tuned Oscillators—T. A. Hunter. (*QST*, vol. 30, pp. 42–46; August, 1946.) A comparison between variable permeability and capacitance-tuned oscillators shows (a) the range of permeability tuning is restricted to about 3 to 1 compared with 4 to 1 for capacitance tuning; (b) less frequency drift occurs with permeability-tuned oscillators during warming-up time, as the total tuning capacitance may be made larger than for capacitance-tuned oscillators with the same frequency range; (c) temperature compensation may be applied to both types of oscillator; and (d) the permeability-tuned oscillator is superior to the other in frequency stability when subjected to mechanical vibration.

621.396.619.018.41 **3104**
F.M. Carrier Stabilization: Part 2—Western Electric, Westinghouse, R.C.A. Circuits—I. Queen. (*Radio Craft*, vol. 17, pp. 605, 637; June, 1946.) For part 1 See 2765 of September.

621.396.619.018.41:621.396.66 **3105**
Direct F.M. Frequency-Control Methods—N. Marchand. (*Communications*, vol. 26, pp. 30–35; July, 1946.) Discussion of three methods for stabilizing the center frequency of a frequency-modulation transmitter which uses a direct system of modulation. Basic circuits for each of the methods are presented and analyzed. Part 7 of a series. For previous parts, see 2767 of September and back references.

621.396.712 **3106**
Canada's New Short Wave Transmitters—H. B. Seabrook and F. R. Quance. (*Elec. Ind.*, vol. 5, pp. 72–74, 105; July, 1946.) Engineering details. See also 193 of January (Smith) and 744 of March (Cahoon).

VACUUM TUBES AND THERMIONICS

621.3.032.216:537.533.8 **3107**
Secondary Electron Emission from Oxide-Coated Cathodes: Part 1—M. A. Pomerantz. (*Jour. Frank. Inst.*, vol. 241, pp. 415–433; June, 1946.) An investigation of factors affecting the yield of secondary electrons under both continuous and pulsed bombardment. The variations of yield and energy distribution with primary voltage and with temperature have been determined, and these and other phenomena are discussed in the light of the present state of the theory

621.314.632.029.62:[546.28+546.289 3108
Crystal Rectifiers—W. E. Stephens. (*Electronics*, vol. 19, pp. 112–119; July, 1946.) A description of the mechanical construction and performance of germanium and silicon rectifiers developed for frequency conversion and signal detection at microwavelengths. The preparation and electrical properties of the materials are described. Noise, stability, and the dependence of the properties on temperature are considered, and properties of 22 types of rectifier with assigned type-numbers are tabulated. See also 1728 of June (Cornelius).

621.385 **3109**
Total Emission Damping with Space-charge-limited Cathodes—C. N. Smyth. (*Nature*, (London), vol. 157, p. 841; June 22, 1946.) Electrical damping at very-high-radio frequencies may be due to emission

from the cathode surface which returned to the cathode after a time comparable with the high-frequency period. The effect could be reduced by cooling the cathode and was not detectable at low frequencies. Such damping behaves as a source of noise with the general characteristics of 'shot' noise.

621.385 **3110**
Valve Standardization—J. W. Ridgeway. (*Wireless World*, vol. 52, pp. 239–240; July, 1946.) Report by the chairman of the British Valve Manufacturers' Association, on progress towards the manufacture of tubes having standard working characteristics.

621.385:003.6 **3111**
Suggested Rules for Symbols in Valve Nomenclature—(*Electronic Eng.*, vol. 18, p. 254; August, 1946.) Extracts from rules proposed by the British Valve Manufacturers' Association for use in technical literature issued by its members.

621.385.1 **3112**
The Effect of Grid-Support Wires on Focusing Cathode Emission—Chai Yeh. (Proc. I.R.E. and Waves and Electrons, vol. 34, pp. 444–447; July, 1946.) A conformal transformation is applied to a half section of a tube system consisting only of anode and cathode, with grid-support wires. Those parts of the cathode that have a positive field adjacent due to electrostatic charges on the electrodes are thereby determined, enabling the angle of electron emission to be found. Curves show the variation of this angle with anode and grid potentials and with electrode dimensions and spacings.

621.385.16 **3113**
The Magnetron—W. E. Willshaw and E. C. S. Megaw. (*Engineering*, (London), vol. 161, pp. 361–363; April 19, 1946.) Illustrated general description.

621.385.16.029.64 **3114**
Rising Sun Pulsed and C.W. Magnetrons—H. G. Shea. (*Elec. Ind.*, vol. 5, pp. 46–50; August, 1946.) The construction and performance of cavity magnetrons with alternate small and large cavities are described. Oscillations in unwanted modes are suppressed with more efficient operation than is obtained with the strapped-anode technique. Other advantages are (a) larger and simpler structure for a given small wavelength (e.g. 6 millimeter), (b) mode separation independent of anode-block thickness, (c) mode separation persists for a relatively large number of cavities (e.g. 38), and (d) copper losses are less than with strapped anodes. An important disadvantage is zero-mode contamination of the wanted π mode for magnetic fields near 12,000/λ oersted. A continuous-wave magnetrons with a tungsten-coil cathode gave 900 watts with 26 per cent efficiency at 2.6 centimeter wavelength.

621.385.3/.4].029.62 **3115**
High Power Tubes for V.H.F. Operation—W. W. Salisbury. (*Communications*, vol. 26, pp. 33, 49; June, 1946.) Survey of triodes and tetrodes giving powers above 1 kilowatt usable at frequencies between 100 and 220 megacycles.

621.385.3.029.63:621.397.61 **3116**
High-Power U.H.F. Tube—(*Radio Craft*, vol. 17, pp. 608, 640; June, 1946.) The 6C22 tube anode dissipation 2 kilowatts, and its use in the Columbia 490-megacycle color-television transmitter.

621.385.38:621.396.619.16 **3117**
Hydrogen Thyratrons—H. Heins. (*Electronics*, vol. 19, pp. 96–102; July, 1946.) A description of the 4C35 and 5C22 tubes developed for use with high-voltage line pulse-forming circuits used for modulating magnetrons. Hydrogen filling gives the required low de-ionization time. The special construction and properties are discussed in relation to the mechanism of the modulator circuits. Switching rates up to 5000 per second have been obtained with the 5C22 with 8 kilovolts and 75 ampere peak current, and rates over 100,000 per second have been obtained with the 4C35 at lower voltages and currents. Possible industrial applications are mentioned.

621.385.4 **3118**
Space Charge and Electron Deflection in Beam Tetrode Theory—S. Rodda. (*Jour. Telev. Soc.*, vol. 4, pp. 182–193; December, 1945. Discussion, pp. 193–195.) Secondary emission from the anode is annulled in beam tetrodes by a sufficient depression of potential in the screen/anode space, produced either by the space charge alone or with the aid of auxiliary electrodes. The potential distribution in the space is calculated by extending Gill's analysis for a plane parallel system (*Phil. Mag.*, vol. 49, pp. 993–1005; 1925). The critical current condition in which a virtual cathode is formed is found to give "knee" voltages (anode voltages at which the characteristic abruptly flattens) much higher than the observed tubes. The assumptions of transverse deflections of the electrons at the grid and screen wires and of reflection at a finite nonzero potential lead to results in fair agreement with experiment.

621.385.4 **3119**
Beam Tetrodes—S. Rodda. (*Wireless Eng.*, vol. 23, pp. 202–203; July, 1946.) Assuming copious emission of secondary electrons with zero velocity, it is shown that the space charge due to the secondary electrons plays an important part in producing a potential minimum in the screen-anode space, when the primary electron flow itself is insufficient for the formation of the minimum. Brief note only.

621.385.4 **3120**
The 6AR6 Tube—E. A. Veazie. (*Bell Lab. Rec.*, vol. 24, pp. 264–265; July, 1946.) Short description of the design and performance of a small beam-tetrode that can operate with 20-watt anode dissipation and 1300-volt anode voltage.

621.385.5:621.395.645 **3121**
Dynamic Characteristics of Pentodes—Haefner. (*See* 2846.)

621.385.5:621.395.645 **3122**
Reentrant Pentode A.F. Amplifier—R. Adler. (*Electronics*, vol. 19, pp. 123–125; June, 1946.) A special pentode operating as two triodes in cascade giving gains up to 500 with a 45-volt plate supply. Control of regeneration and design precautions to be observed are discussed. The second grid forms the anode of the first triode, and the third grid and plate form the second triode.

621.385.832 **3123**
The 5RP Multiband Tube: An Intensifier-Type Cathode-Ray Tube for High-Voltage Operation—I. E. Lempert and R. Feldt. (Proc. I.R.E. and Waves and Electrons, vol. 34, pp. 432–440; July, 1946.) The performance at frequencies up to 100 megacycles is improved by increasing the trace intensity by means of several cylindrical intensifying electrodes introduced into the region between the deflecting plates and screen. The distortions caused by an excessive ratio of intensifier potential to second-anode potential are illustrated, and the design to enable a ratio of 10 to 1 to be used is described. Applications to high-speed transient recording and projection are suggested, and the extension of the frequency range to 1000 megacycles using coaxial connections to the deflecting plates is proposed.

621.385.832.032.2 **3124**
The Electron Gun of the Cathode Ray Tube: Part 2—H. Moss. (*Jour. Brit. Inst. Radio Eng.*, vol. 6, pp. 99–129; June, 1946.) Conclusion of 3534 of 1945. An extended practical treatment is given of the factors entering into the design of the triode portion of the tube, in which its characteristics are related to the electrode voltages and geometry. The results of this section are summarized in tabular form. Relevant data are given for a number of cathode-ray tubes in general use, for which the smallness of the useful cathode area "demonstrates how vital is the fine structure of the emitting cathode surface." Discussion included.

621.386.1 **3125**
X-Ray Tubes with Rotating Anode ("Rotalix" Tubes)—van der Tuuk. (*See* 3075.)

621.396.822:621.385.2 **3126**
"Shot-Effect" in Diodes Under Retarding Field Conditions—R. Fürth and D. K. C. MacDonald. (*Nature*, (London), vol. 157, p. 841; June 22, 1946.) Experiments were carried out with a number of close-space diodes over a wide range of current up to a limiting current I_e, and shot effect was measured as under saturated conditions. A discrepancy of up to 10 to 1 was found between the theoretical and practical values of I_e. This can be explained by the existence of a potential barrier at the anode surface which would prevent slower electrons from penetrating into the anode.

621.396.822:621.3853 **3127**
Fluctuations in Electrometer Triode Circuits—van der Ziel. (*See* 2833.)

MISCELLANEOUS

001.89 **3128**
Organization of Scientific and Industrial Research—(*Nature*, (London), vol. 157, pp. 565–568; May 4, 1946.) An editorial discussion of recent proposals for organization on a national scale, with particular reference to the Bush report (see 492 of February) and the discussion of it by other authorities.

001.89(410) 3129
Scientific and Industrial Research in Great Britain—(*Nature*, (London), vol. 157, pp. 709–712; June 1, 1946.) An editorial account of the scope, responsibilities, and activities of the Department of Scientific and Industrial Research and future trends in its research program.

001.89(410) 3130
[Scale of Grants to Workers and Students for] Scientific and Industrial Research in Great Britain—O. F. Brown. (*Nature*, (London), vol. 157, p. 879; June 29, 1946.)

001.89:6 3131
Industry and Research—(*Engineer*, (London), vol. 181, pp. 312–314; April 5, 1946; and *Nature*, (London), vol. 157, pp. 684–686; May 25, 1946.) An account of a conference under the auspices of the Federation of British Industries. The main speeches and discussion covered education and research in large and small firms and in government laboratories.

001.891:629.13 3132
Aviation and Scientific Research—M. Griaule. (*Nature*, (London), vol. 157, pp. 848–849; June 22, 1946.) Section formed under the auspices of the Congrés de l'Aviation Française. Research investigations using aircraft may be classed under the three headings: stratosphere, atmosphere, and earth's surface.

001.891:8–96 3133
Rationalization of the Literature of Scientific Research—(*Nature*, (London), vol. 157, pp. 745–748; June 8, 1946.) The necessity for an organization to deal with scientific literature.

061.5:621.317.2.027.8 3134
The New Brown Boveri High-Tension Testing Laboratory—W. Wagner. (*Brown Boveri Rev.*, vol. 30, pp. 212–217; September and October, 1943.) **The Installations of the New Brown Boveri High-Tension Testing Laboratory.**—F. Beldi and C. Degoumois. (*Brown Boveri Rev.*, pp. 218–221.) Abstracts in *Rev. gén. Élec.*, vol. 55, p. 1D.; January, 1946.

061.5:621.381.39 3135
War Years' Review: Part 1—(*Elec. Commun.*, vol. 23, pp. 3–18; March, 1946.) A survey of the wartime activities of Standard Telephones and Cables, Ltd., London and Sydney. The first of a series describing the wartime work of the International Telephone and Telegraph associates.

061.5:621.39 3136
Telecommunications Research—(*Electrician*, vol. 136, p. 1513; June 7, 1946.) Brief report of the achievements of the Marconi's Wireless Telegraph Co. in high-speed communications and ionospheric work.

061.6 3137
The National Physical Laboratory—(*Engineer* (London), vol. 181, pp. 590–591; June 28, 1946.) An account of the first postwar annual exhibition of work in progress.

061.6:621.3.027.3 3138
The Parsons Memorial Lecture: "High-Voltage Research at the National Physical Laboratory"—R. Davis. (*Jour. I.E.E.* (London), part I, vol. 93, pp. 177–186; April, 1946.) An account of the methods of producing and measuring high direct-current power-frequency, and surge voltages, and the application to the protection of high-voltage transmission lines and barrage balloons. See also 2415 of August.

347.771 3139
Patent Law Proposals—(*Engineer* (London), vol. 181, pp. 513–515; June 7, 1946.) Recommendations of changes to improve the British Patents and Designs Acts.

5+6]:621.396.97 3140
Science and Radio—(*Nature*, (London), vol. 157, pp. 757–758; June 8, 1946.) A conference to consider the contribution of the British Broadcasting Corporation to the promotion of scientific knowledge.

5+6][(437)+(436.9) 3141
Science in Czechoslovakia and Yugoslavia—(*Nature*, (London), vol. 157, p. 487; April 13, 1946.)

534.1 3142
Some Notes on Vibration Analysis—R. J. Manley. (*Jour. Roy. Aeron. Soc.*, vol. 49, pp. 419–426; July, 1945.) An outline of the fundamental process of solving vibration problems by applying Lagrange's equation to a system of idealized inertia, spring, and dissipative elements made to represent the actual system. The analysis includes an account of the concepts of natural modes, equilibrium amplitudes, and dynamic magnifiers.

551.5:629.135:621.396.6 3143
The Effects of Atmospheric Conditions on Aircraft Radio Equipment—W. W. Honnor. (*A.W.A. Tech. Rev.*, vol. 6, pp. 529–551; March, 1946.) Describes laboratory test chambers for simulating the ranges of temperature, pressure and humidity likely to occur. Direct-current flash-over voltages of cable connectors are given for saturated air at 35,000 feet and corona voltages at 300 kilocycles are given for a large number of materials. A circuit is described for the measurement of flash-over voltages of sphere-gaps at 2.5 megacycles and 19 megacycles and curves show the variation of spark-over voltage with altitude for spacings of 0.05 inch to 0.50 inch. Results are also given for spark-over voltages of variable capacitors, including a wire close to a conducting plane, in air at a pressure of 7 inches of mercury for frequencies up to 20 megacycles.

6(07) 3144
Science and Education—E. G. Carter. (*Nature*, (London), vol. 157, pp. 344–345; March 16, 1946.) An account of a conference of the Association of Scientific Workers.

62.004.11 3145
Preparation and Use of Specifications—G. Reinsmith. (*Bull. Amer. Soc. Test. Mat.*, pp. 41–44; March, 1946.)

62.004.11:519.283 3146
Use of Statistics in Writing Specifications—C. Goffman and J. Manuele. (*Bull. Amer. Soc. Test Mat.*, pp. 13–17; March 1946.)

62.004.11:519.283 3147
Dollars for Your Thoughts—L. E. Simon. (*Bull. Amer. Soc. Test Mat.*, pp. 17–21; March, 1946.) An account of the advantage of framing specifications on the basis of statistical methods and quality control carefully design to produce the required results.

621.3.025 3148
Demonstration Devices—W. K. Allan. (*Radio Craft*, vol. 17, pp. 532, 571; May, 1946.) Description of mechanical and electrical devices for demonstrating alternating current and voltage relationships in circuits.

621.315.1.056.1 3149
Tensions in Hanging Wires—Hookham. (*See* 2808.)

621.38/.39](43) 3150
German Electronic Equipment—(*Wireless World*, vol. 52, pp. 163–164; May, 1946.) Account of equipment at the Earls Court Exhibition. See also 2438 of August.

621.396(43) 3151
Communications in Germany—P. Mertz. (*Bell Lab., Rec.*, vol. 24, pp. 271–274; July, 1946.) The Germans had a broad-band cable network for multicarrier telephone and television between the principal cities; wired wireless was extensively used. In the television field, large-screen projectors with definition up to 1000 lines were envisaged. Much work was being done on photo-sensitive materials.

621.396.611 3152
A Mechanical Model Analogous to an Oscillatory Electrical Circuit—G. G. Blake. (*Engineer* (London), vol. 181, pp. 535–536; June 14, 1946.) The model can be used to show variations in the Q of an oscillatory circuit or to illustrate resonance between an oscillator and a second tuned circuit.

621.396.621.003.1(4) 3153
Report on European Radio Industry—L. Laden. (*Radio News*, vol. 35, pp. 25, 114; May, 1946.) Report on the European demand for domestic radio and television receivers, and the capability of the American radio industry to supply them.

001.89 3154
[British] Industrial Research and Development. [Book Review]—F. Heath and A. L. Hetherington. Faber and Faber, London, 1946, 25s. (*Engineer* (London), vol. 181, pp. 477–478; May 24, 1946.) A very favorable review.

016:[621.38/.39 3155
The Electronic Engineering Master Index. [Book Review]—F. A. Petraglia (Editor). Electronics Research Pub. Co., New York, 1945, 317 pp., $17.50. (*Electronics*, vol. 19, pp. 324, 326; May, 1946.) See also 2108 of July.

621.396.029.64 3156
Understanding Microwaves. [Book Review]—V. J. Young. J. F. Rider, New York, 400 pp., $6.00. (*Radio*, vol. 30, pp. 45–46; May, 1946.)

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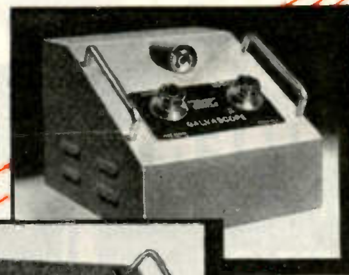

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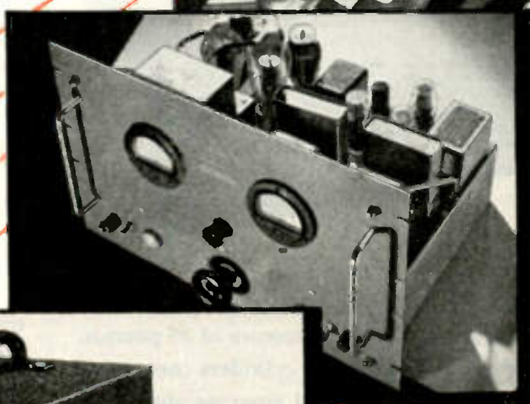

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SECTION MEETINGS

Atlanta

"Urban Mobile Radiotelephone Systems," by B. Branch and J. W. Hudson, Southern Bell Telephone and Telegraph Company; August 23, 1946.

Buenos Aires

"Patent Terminology," by B. Noviks, May 23, 1946.

"Magnetic Recording," by N. C. Cutler, June 14, 1946.

Buffalo-Niagara

"The New Bell System Mobile Radio Telephone," by Don De Wire, New York Telephone Company; September 18, 1946.

Cedar Rapids

"High Frequency High Fidelity A. M. Broadcasting," by Sarkes Tarzian, Consulting Engineer; September 11, 1946.

Chicago

"A New Noise Limiter for Communications Receivers," by G. J. C. Andresen, Goodyear Research Laboratories; September 20, 1946.

"A Fixed Channel Communications Receiver with Improved Noise Limiting," by E. A. Jensen, United Air Lines; September 20, 1946.

Cincinnati

"New Methods in the Air Navigation Program," by H. I. Metz, Civil Aeronautics Authority; September 17, 1946.

Cleveland

"Radio Relay Development by Radio Corporation of America," by C. W. Hansell, Radio Corporation of America; May 16, 1946.

Election of Officers; May 16, 1946.

Dallas-Ft. Worth

"Charting the Course of the I.R.E.," by F. B. Llewellyn, President of the Institute of Radio Engineers; September 17, 1946.

Detroit

"Developments and Trends in Electronic Tubes," by L. G. Hector, Sonotone Corporation; September 20, 1946.

Houston

"Charting the Course of the I.R.E.," by F. B. Llewellyn, President of the Institute of Radio Engineers; September 16, 1946.

Indianapolis

"A Non-Mathematical Review of Design Considerations and Application Problems of Coaxial Transmission Lines," by C. R. Cox, Andrew Company; September 27, 1946.

Kansas City

"Recent Developments in Microwave Electronics," by A. L. Samuel, University of Illinois; May 28, 1946.

Los Angeles

"Precision Miniature Tubes for V.H.F. and Multivibrators," by M. H. Brown, Western Electric Company, Inc.; July 16, 1946.

New York

"Reflex Oscillators for Radar Systems," by J. O. McNally and W. G. Shepherd, Bell Telephone Laboratories; September 4, 1946.

"An Internally Neutralized Duplex Power Tetrode," by P. T. Smith and H. R. Hegbar, Radio Corporation of America Laboratories; September 4, 1946.

(Continued on page 36A)

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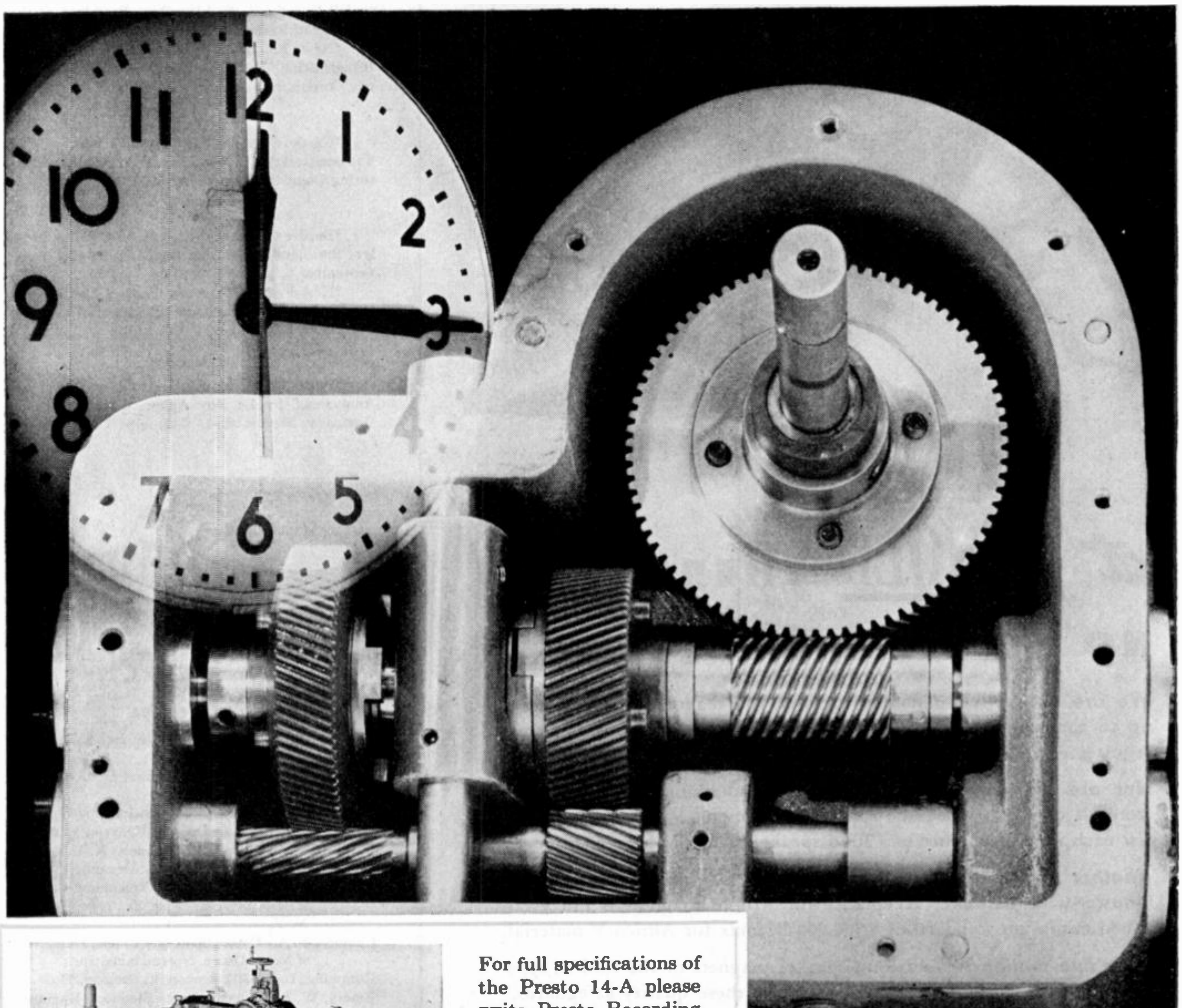

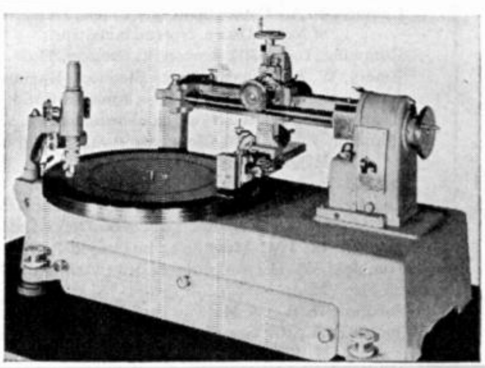

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SECTION MEETINGS

(Continued from page 34A)

OTTAWA

"Work of the Canadian Council of the I.R.E. Its Past, Present and Future Plans and Plans of the Canadian Council of Professional Engineers," by F. S. Howes, Chairman of the Canadian Council of the Institute of Radio Engineers; May 16, 1946.

Election of Officers; May 16, 1946.

PORTLAND

"Matters of Current Interest and Importance to I.R.E.," by F. B. Llewellyn, President of the Institute of Radio Engineers; September 4, 1946.

"New Frequency Control Circuit for FM Broadcasting," by W. U. Dent, Westinghouse Electric Corporation; September 11, 1946.

ST. LOUIS

"Cascade Phase Shift Modulation for FM Transmitters," by S. G. Jones, Raytheon Manufacturing Company; September 19, 1946.

SAN FRANCISCO

"Future Course of the I.R.E.," by F. B. Llewellyn, President of the Institute of Radio Engineers; September 6, 1946.

"New F. M. Frequency Control Circuit," by W. U. Dent, Westinghouse Electric Corporation; September 19, 1946.

WILLIAMSPORT

"Wide-Range Double-Heterodyne Spectrum Analyzers," by Le Roy Apker, General Electric Company; September 4, 1946.

MEMBERSHIP

The following transfers and admissions were approved on October 1, 1946:

Transfer to Senior Member

Abbott, W. R., Engineering Annex, Iowa State College, Ames, Iowa
Ackerman, E. K., RFD 1, Brooklyn, Station, Cleveland 9, Ohio
Adams, E. L., Miami Valley Broadcasting Corporation, 45 S. Ludlow St., Dayton 1,Ohio
Barone, S. A., 298 Rose St., Freeport, N. Y.
Boese, W. C., 3217 Gunston Rd., Alexandria, Va.
Chick, A. J., Rm. T-234, Bell Telephone Laboratories, Inc., 463 West St., New York 14, N. Y.
Coomes, E. A., Department of Physics, University of Notre Dame, Notre Dame, Ind.
Cumming, L. G., 504 Beacon St., Boston, Mass.
Emery, W. L., Department of Electrical Engineering, Iowa State College, Ames, Iowa
Evans, H. J., 822 Reservoir St., Lancaster, Pa.
Franklin, L. W., 224 Cleveland Ave., Hasbrouck Heights, N. J.
Garard, E. A., 330 D Ave., Coronado, Calif.
Goyder, C. W., All India Radio, Broadcasting House, Parliament St., New Delhi, India
Herbert, C., 1541 Mars Ave., Lakewood 7, Ohio
Hudgins, W. D., 4 Columbia Rd., Arlington 74, Mass.
Jacobus, H. R., 39 Midway Dr., Livingston, N. J.
Jenks, F. A., 109 Greystone Rd., Rockville Centre, N. Y.
Killian, L. G., 1449 West Fargo Ave., Chicago 26, Ill.

(Continued on page 38A)

MEMBERSHIP

(Continued from page 36A)

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Monroe, R. B., 279 Summit Ave., Mount Vernon, N. Y.
Morton, G. A., 200 Library Place, Princeton, N.J.
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Smith, N., Central Radio Propagation Laboratory, National Bureau of Standards, Washington 25, D. C.
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Watts, D. E., Bldg. C., General Electric Co., Thompson Road Plant, Syracuse, N. Y.
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Woodward, C. A., Jr., 275 Massachusetts Ave., Cambridge 39, Mass.
Wulfsberg, P. G., Collins Radio Co., Cedar Rapids, Iowa

Admission to Senior Member

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Gable, A. C., Tube Division-Engineering, General Electric Co., Schenectady 5, N. Y.
Getting, I. A., 127 Winn St., Belmont 78, Mass.
MacKinnon, K. A., Box 542, Ottawa, Canada
McClellan, G. B., 49-24 Forest Dr., Douglaston, L. I., N. Y.
Molnar, I., 1033 Van Buren St., Chicago 7, Ill.
Moon, R. J., Physics Department, Botany Bldg., University of Chicago, Chicago 37, Ill.
Rowland, H. J., 19 Hamilton Rd., Brookline, Mass.
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Berg, B., Box 556, RFD 7, Akron, Ohio
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Brown, E. W., 432 W. 27 Ave., Gary, Ind.
Butts, H. H., 22 Bradford Ave., Passaic, N. J.
Carlson, L. T., WKBB, 505 Main St., Dubuque, Iowa
Coffin, G. C., c/o Montreal Aeradio, Department of Transport, Montreal 33, Que., Canada

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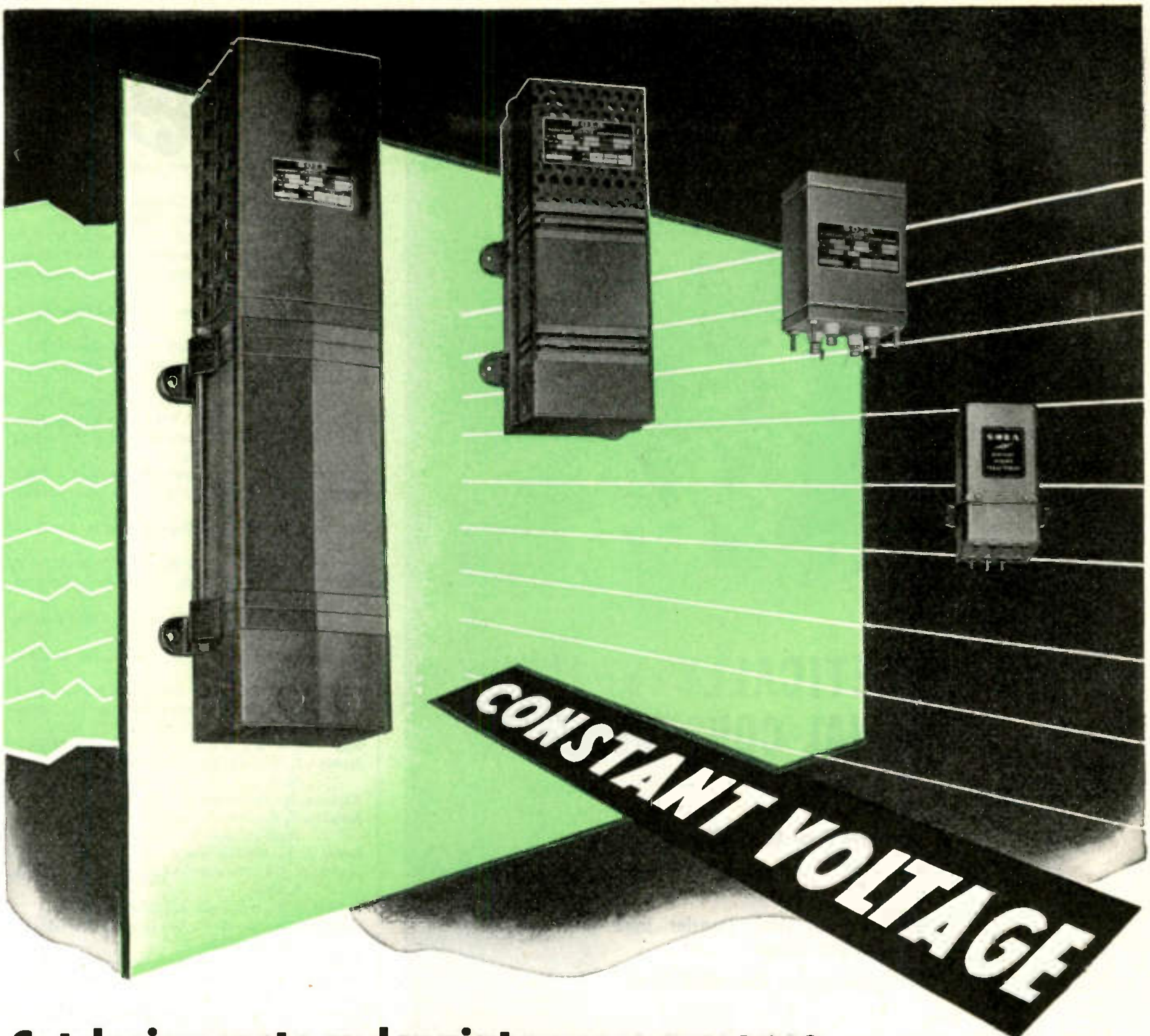

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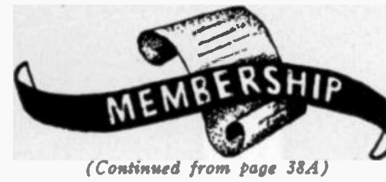

(Continued from page 38A)

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Pontius, J. C., 56 Morningside Lane, Williamsville 21, N. Y.
Pound, J. P., c/o Barclays Bank Ltd., Chesterton Rd., Cambridge, England
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Rice, S. M., 1902 23 St., S. E., Apt. 93-B, Washington 20, D. C.
Rizk, K. S., Electronics Division, Bureau of Aeronautics, Navy Department, Washington 25, D. C.
Roberts, F. F., Radio Branch (W41), Research Station, London N. W. 2, England
Rod, R. L., 145 E. 49 St., New York 17, N. Y.
Steen, W. J., 3041 N. Nagle Ave., Chicago 34, Ill.
Tremblay, C. E., Rm. 1008, Lindsay Bldg., Winnipeg, Man., Canada
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Wise, H. G., 1705 N. 48 St., East St. Louis, Ill.
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Zelle, J., 1227 Addison Rd., Cleveland 3, Ohio

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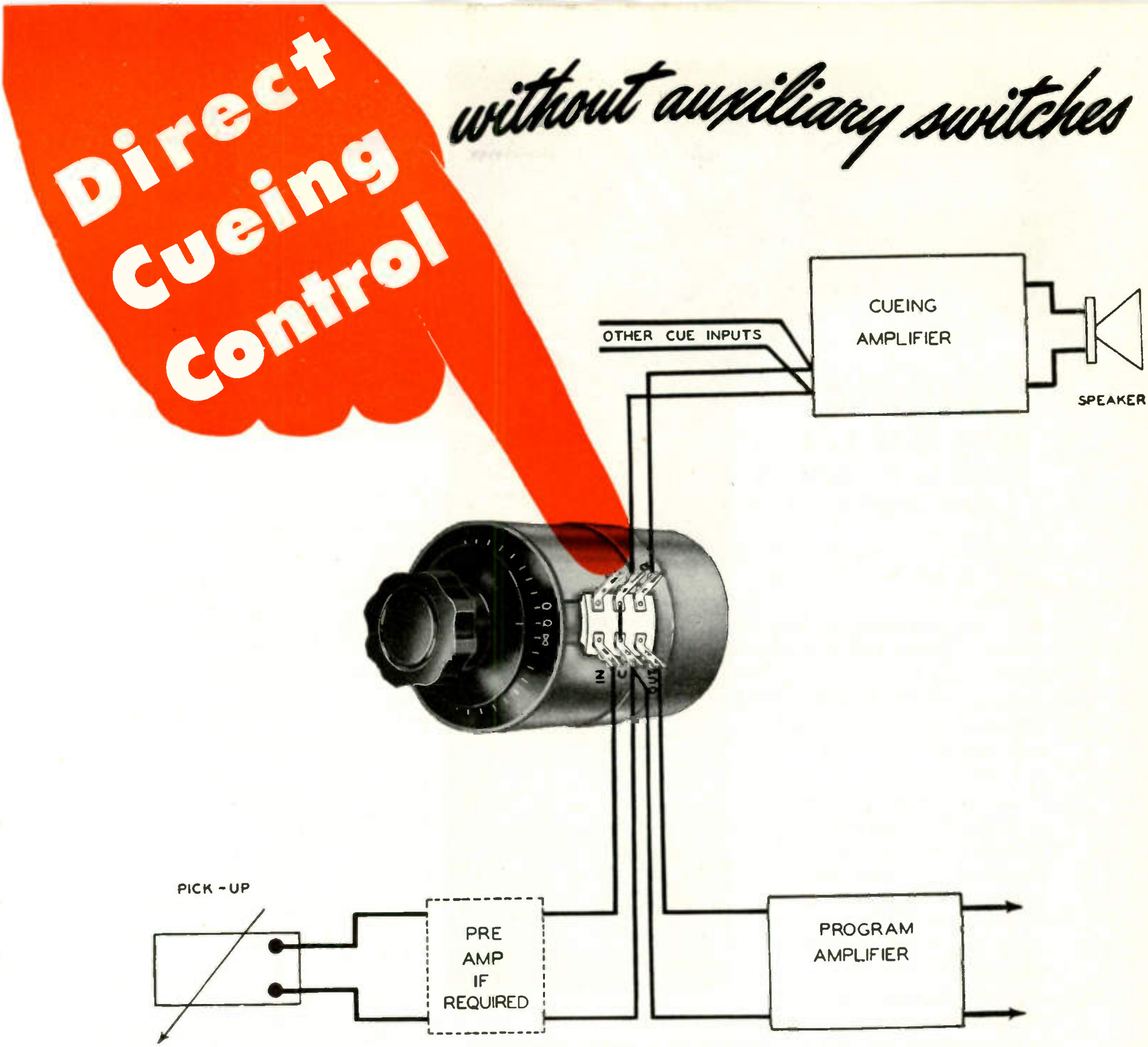
Budd, R. W., 6126 N. Wilbur St., Portland 11, Ore.

(Continued on page 42A)



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(Continued on page 44A)

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STYLES	MIN.	MAX.
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S	222	460 MMF
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F	1391	1770 MMF

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- **K:** 135 approx.
- **Flash Test:** 1300 volts D. C.
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The Erie N1400 Ceramicon series has the same characteristics as other Erie temperature compensating Ceramicons; definite and entirely reproducible temperature coefficient of capacity, high Q factor, and inherent stability. Electrical characteristics and capacity ranges are given at the left.

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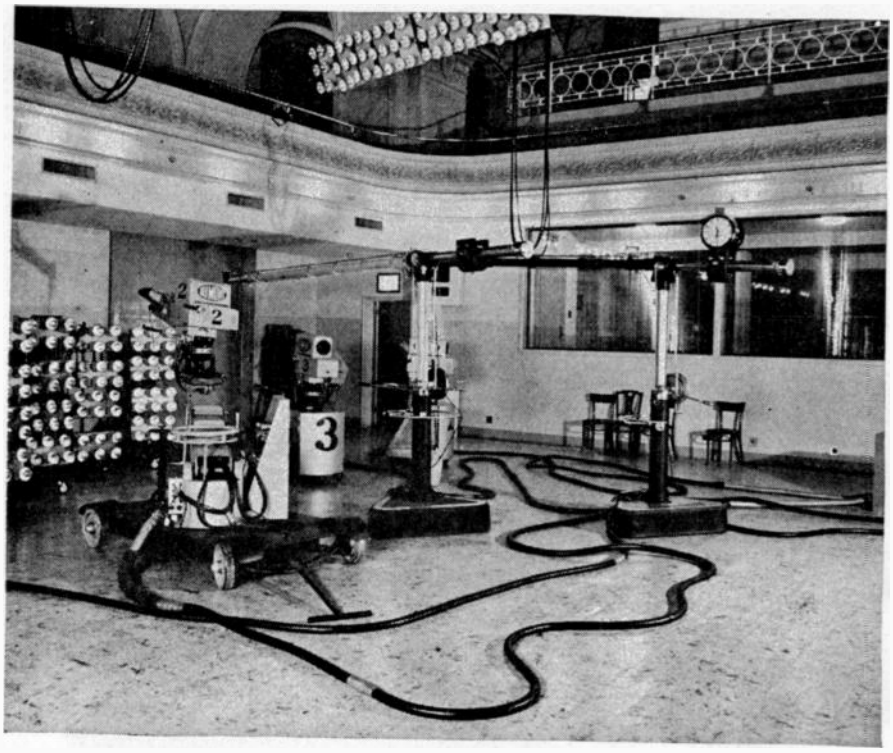

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(Continued from page 42A)

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(Continued on page 46A)

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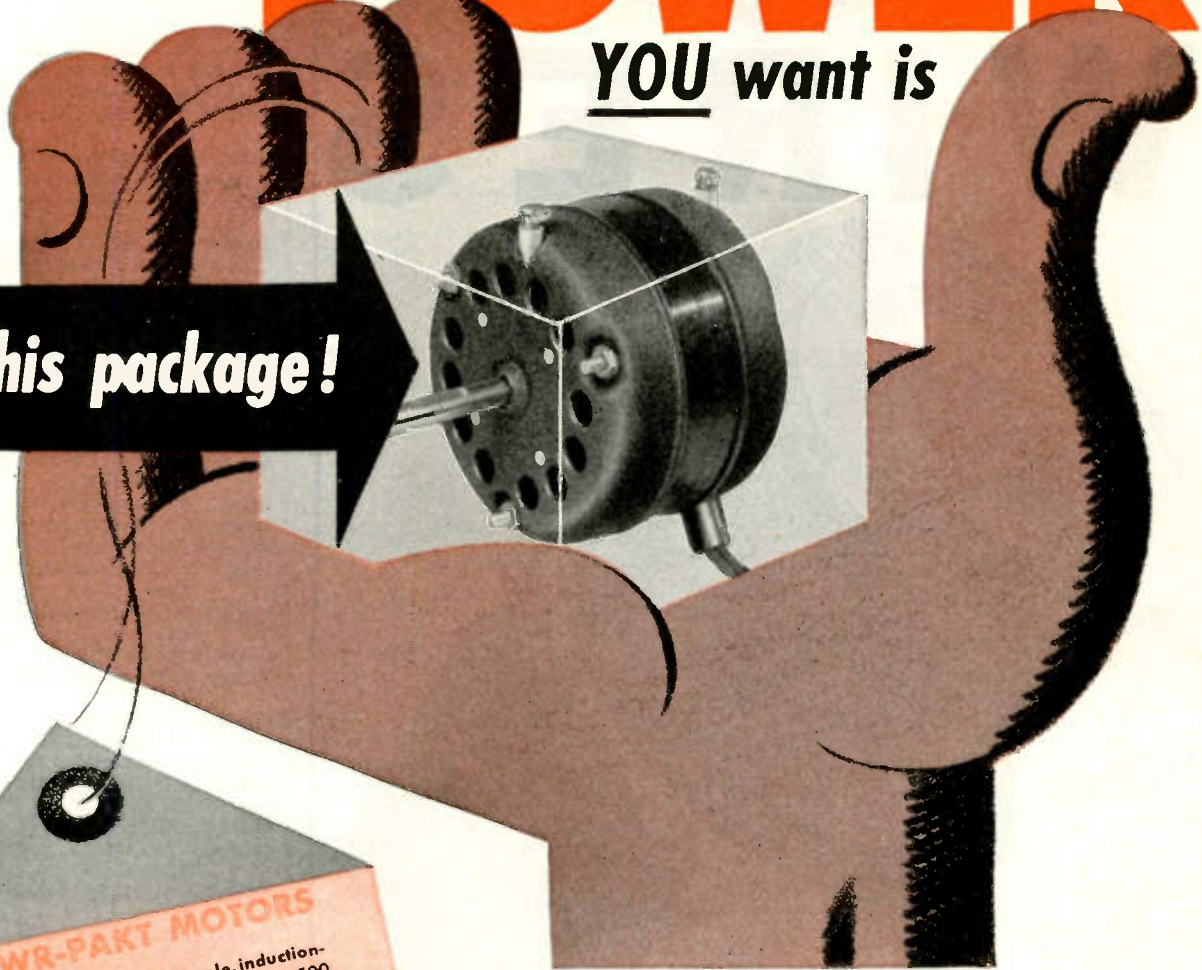

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Johnson, C. K., 2803 Quincy, Kansas City 3, Mo.
Kalakowsky, C. B., 63 Dracut St., Dorchester 24, Mass.
Kampinsky, A., 212—11 Ave., Belmar, N. J.
King, S. W., Apt. 203, 3012 S. Halldale Ave., Los Angeles 7, Calif.
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Needed for extensive laboratory development work in circuit detailed investiga-

(Continued on page 52A)

POSITIONS OPEN

(Continued from page 50A)

tion 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

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Training will be given to cover any deficiencies applicant may have. In reply state age, education, sales and engineering experience and other qualifications. Include three references and photograph. Box 435.

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SP-7 and P1-P5 inclusive. Work involves the development and design of small and intricate electro-mechanical integrating and computing systems. The de-

(Continued on page 54A)

POSITIONS OPEN

(Continued from page 52A)

sign and development of computing machines, fire control devices, automatic pilots, or similar devices represent the type and scope of work.

P-5. Must have background in the design and development of electronic and associated mechanical devices, with marked ability in administration and the preparation of technical papers and reports. Must have excellent personality.

Feminine applicants will be carefully considered for this position.

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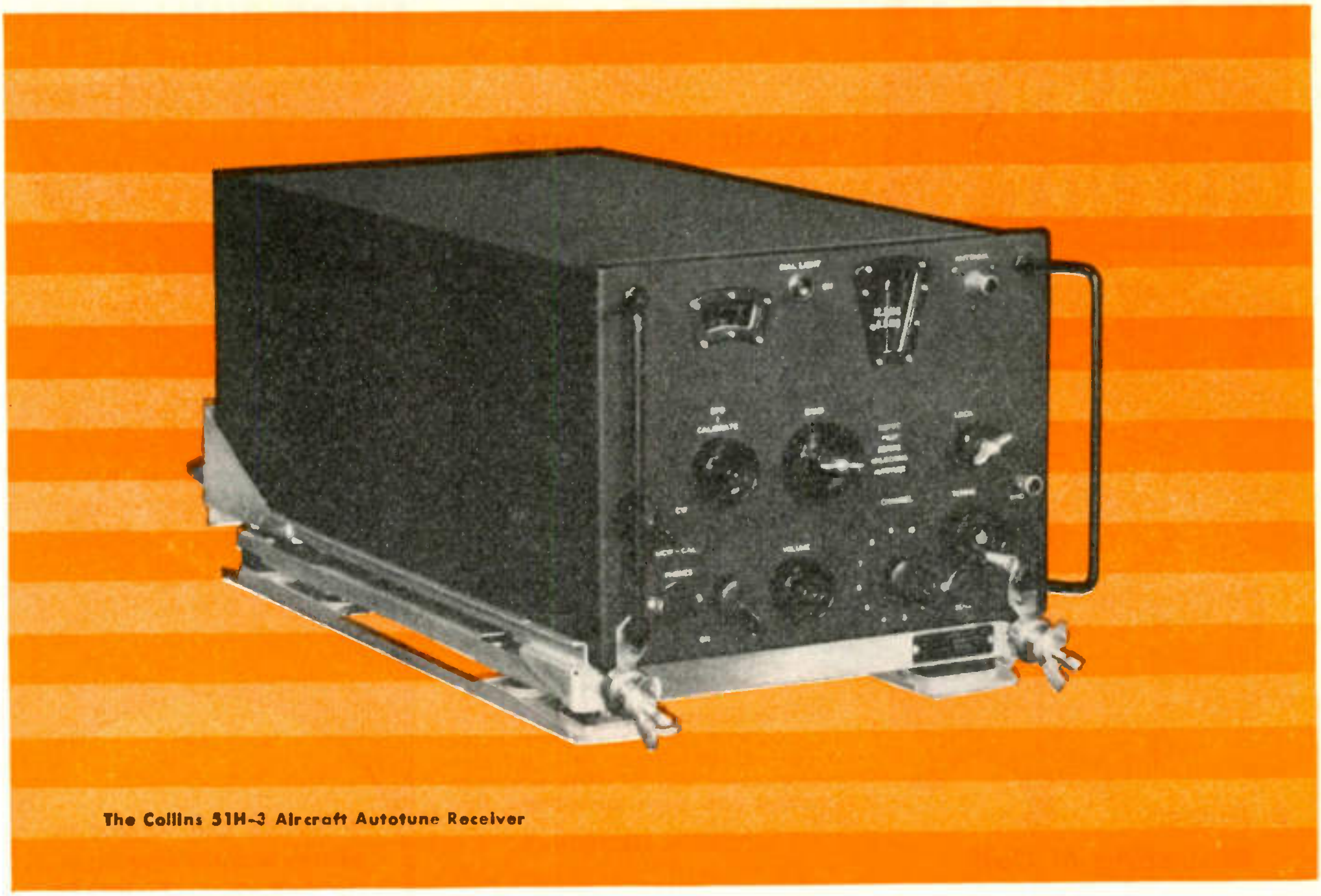
News—New Products

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

New Enterprises

• • • *Eastern Industries, Inc.*, was formed recently to take over the entire business of *Automatic Signal Company*, East Norwalk, Conn., and *Eastern Engineering Corp.*, New Haven, Conn.

(Continued on page 60A)



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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 by February 1947. Senior work in E.E. completed. Requires two non-electrical subjects for degree now taking in evening school. Age 27. Desires start in electronics field. Army meterologist. Box 47W.

INDUSTRIAL ELECTRONICS

BSEE Wisconsin, some graduate work at Northwestern. Eta Kappa Nu and Tau Beta Pi. 2½ years broadcast station control engineer, 1 year electronics instructor, 2½ years development and production airborne radar equipment, 1½ years in service with OSRD new developments division. Desires position involving design and development of industrial electronics applications. Will consider foreign service. Box 48W.

COMMUNICATIONS ENGINEER

BS Engineering, Physics, Toronto. Age 26. 3 years Naval Officer in charge of operating and maintaining all radar equipment aboard cruiser. 1 year field engineering commercial FM radio. Seeks opportunity for original work U.S. or Canada in electronics. Box 49W.

ENGINEER

BSEE, Age 33, married. M.I.T.-Harvard trained electronics-radar officer, SigC, desires position of sales engineer or development of radar and allied fields. Sales, administrative, and manufacturing experience. Box 50W.

ELECTRICAL ENGINEER

BEE. Industrial experience in electrical test planning. Radio and radar experience in Army Signal Corps. Interested in Radio and Electronics. Age 23. Will work within 300 miles of New York City. Resume upon request. Box 51W.

ENGINEER

BSEE Purdue University and M.I.T. trained electronics officer. Age 28, married Experience with Naval radar, sonar, and loran while serving three years afloat. Civilian experience in transformer design and with utility. Desires permanent position in Midwest. Box 52W.

(Continued on page 58A)

Positions Wanted

JUNIOR ENGINEER

BEE, recent graduate N.Y.U. Age 25. Desires position in research, development and design of servo electronic controls or micro-wave research and development. New York City or vicinity. Jesse Goodman, 1695 Hoe Ave., New York 60, N.Y.

BEGINNING ENGINEER

BS in EE. Northwestern University. Age 21. Desires research, development, or production engineering in television. Radar Gunnery Officer. W. L. Morrison, 2032 Highland Ave., Wilmette, Illinois.

RADIO TECHNICIAN

Signal Corps Officer. Age 35. Graduate RCA, Press Wireless, A.T.&T. courses. Five years extensive installation, operation and maintenance of high-power stations. 1st Class Phone License. Will travel. M. G. Gerstein, 1304 Grant Ave., New York 56, N.Y.

ELECTRONICS TECHNICIAN

Three years teaching, total experience 13 years. Desires opportunity in research laboratory, teaching, FM or television radio station work, theater sound maintenance, or commercial sound work. Box 53W.

SALES ENGINEER

17 years' experience all phases broadcast engineering. 4 years AAF as CO communications group, extensive experience aeronautical radio and navigational aids. Age 36. Desires permanent responsible position with progressive company. Will consider foreign assignment. Box 34W.

ELECTRONICS ENGINEER

MA in physics, MS in communications engineering. Three years' experience as physicist for U. S. Navy, both as civilian and officer. Desires position in electronics or physics, environs of New York City or Washington, D.C. Age 30. Box 35W.

ENGINEER

USNA BS, Harvard MS radio engineering, Commander USN. 13 years' naval electrical, engineering, and command experience. Age 43. Desires executive or administrative position. Boston, Mass. Available October 1946. Box 36W.

ENGINEER

BEE, age 24, married. 1½ years' broadcast engineer, NDRC UHF research; two years' Signal Corps Officer. Experienced in police communications. Prefer Chicago area. Available October. Box 37W.

ENGINEER

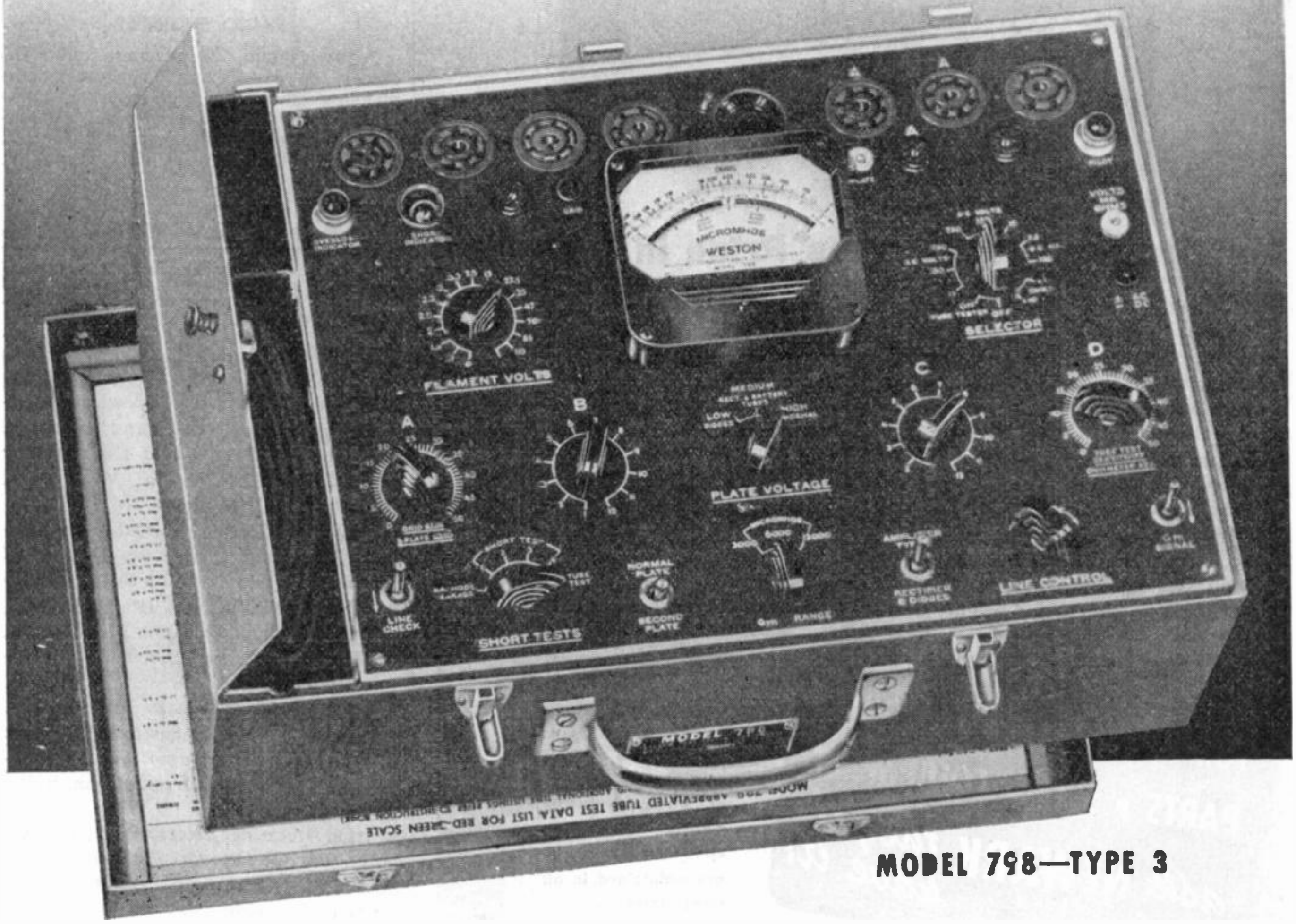
BS in EE, Vermont 1941, age 29. Radar training M.I.T. 4 years' Naval Officer, specializing in maintenance and installaton of radar, and radio equipment aboard aircraft. Interested in research and development. Box 38W.

BROADCAST CHIEF ENGINEER

BS in EE, age 28, radar project engineer, Aircraft Radio Laboratory, and Radiation Laboratory M.I.T. 50 KW broadcast experience. Desires position as Chief Engineer or project Engineer. Prefers Midwest or West Box 39W.

(Continued on page 60A)

NEW! WESTON Mutual Conductance Tubechecker and Circuit Analyzer



MODEL 798—TYPE 3

Outstanding Features

- ✓ Direct-reading mutual conductance tests, and "Good-Bad" indications.
- ✓ New patented high frequency tube testing circuit.
- ✓ AC-DC volt-ohm-milliampere ranges.
- ✓ Tests 4, 5, 6, 7 prong octal, loctal, miniature, and acorn tubes...spare octal and miniature sockets.
- ✓ Hot neon leakage test between any two tube elements... neon short check.
- ✓ Adjustable plate, screen, grid bias, and signal voltages.
- ✓ Flexibility in switching simplifies testing present and future tubes.
- ✓ Durable heavy-gauge, light-weight alumium case.

Model 798 combines broad utility, ruggedness, and dependable accuracy for maintenance of sound and electronic equipment. Detailed bulletin available. Weston Electrical Instrument Corporation, 589 Frelinghuysen Avenue, Newark 5, New Jersey.

Weston Instruments

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Positions Wanted

(Continued from page 58A)

ENGINEER

BS in EE, S.C. Harvard and M.I.T. electronics courses, advanced AAF electronics installation and maintenance; practical radio and industrial electronic and general EE experience; AAF Reserve Major, desire engineering position on West Coast. Box 26W.

RADIO ENGINEER

Army captain, 26, graduate radio engineer, one year research, three years' commanding officer of large radar installations; good appearance, pleasant personality. Interested in engineering sales, finance, or administrative work. Box 27W.

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 54A)

Recent Catalogs

• • • On Motor Starters, Speed and Voltage Regulators, Resistors and Rheostats, Switches and Relays, and Dimmers, by *Ward Leonard Electric Co.*, Mt. Vernon, New York, N. Y. Bulletin No. 100,000.

• • • On Sheet Metal Fabrication for Cabinets, Cases, and Chassis, by *Karp Metal Products Co., Inc.*, 139 30th Street, Brooklyn, N. Y. Bulletin No. 1046.

• • • On Cardioid Dynamic Microphones, by *Electro-Voice, Inc.*, Buchanan, Michigan. Bulletin No. 131.

• • • On Variable Voltage Transformers, Automatic Voltage Regulators, and Test Instruments, by *Superior Electric Company*, 713 Laurel St., Bristol, Conn. Bulletin No. 150.

• • • On Rotating Electrical Equipment, by *Electric Specialty Co.*, 222 South Street, Stamford, Conn. Catalog No. 46-1.

• • • On Resonant Relays, by *Stevens-Arnold Company*, 22 Elkins Street, South Boston 27, Mass. Catalog No. 116.

• • • On Electronic Induction Heating and High Frequency Dielectric Preheating Equipment, by *Illinois Tool Works*, 2501 N. Keeler Ave., Chicago 39, Ill. Bulletin No's. 437-R and 436-R.

• • • On Incremental Inductance Bridges, by *Industrial Transformer Corp.*, 2540 Belmont Ave., New York 58, N. Y.

• • • On Temperature-Resistance Characteristics of Electrical Insulation, by *James G. Biddle Co.*, 1211 Arch St., Philadelphia 7, Pa. Technical Publication No. 21T4.

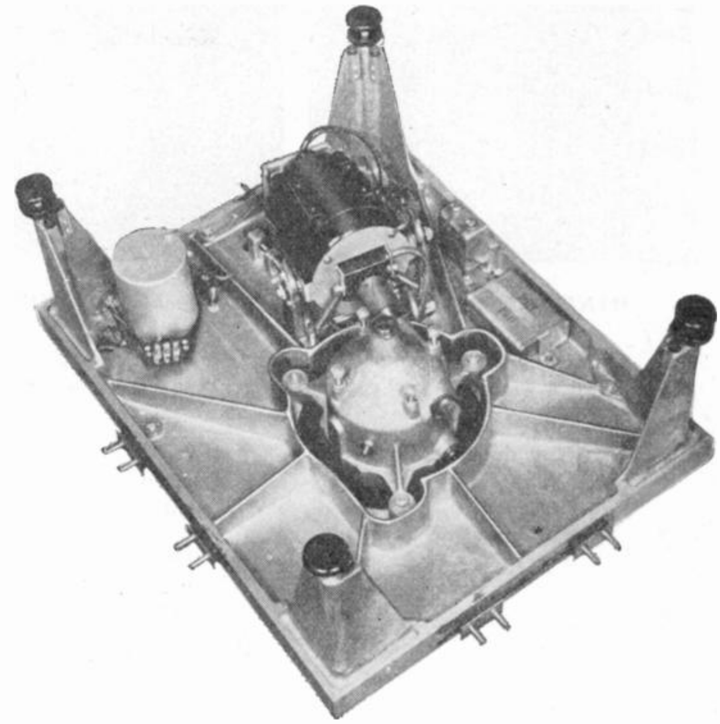
• • • On Tachometers, and Speed Indicators, by *James G. Biddle Co.*, 1211 Arch Street, Philadelphia 7, Pa. Bulletin No's. 1810 and 1815.

• • • On Pulsing Drives for Motor Control, by *YardEny Laboratories, Inc.*, 105 Chambers Street, New York 7, N. Y.

• • • On Ionic-Flash Tube, Type HD72, by *Hytron Radio & Electronics Corp.*, 76 Lafayette St., Salem, Mass.

(Continued on page 64A)

Console STABILITY



Unit 539 Portable Recorder

...for professional portable recorders!

Once again, Fairchild takes the lead in improved sound equipment design—*for even finer performance.* This time it's the new cast panel and motor mount for the Unit 539 Portable Recorder, shown above.

By replacing the former lightweight panel with a sturdy, ribbed casting with integrally cast legs, Fairchild brings console stability to professional portable recorders. The full weight of the recorder mechanism is supported independently of the trunk. The entire mechanism can be removed as a unit, if desired, and leveled up on its own four legs on a bench for operations or mechanical adjustment.

Here again, Fairchild is thinking ahead in terms of increasingly higher standards of performance for both AM and FM broadcasting and professional recording by adding vibration-free performance to already attained wide dynamic range, minimum distortion content, wide frequency range and split-second timing.

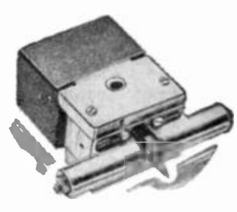
Unit 539 Portable Recorder, mounted in a trunk for portability, is designed to meet and exceed professional specifications for direct lateral recording and reproduction of sound on discs up to 16″ at 33.3 rpm and 78 rpm. It is complete with cable and connectors for attachment to Fairchild Unit 540 and 295 Amplifier-Equalizers.

Where double turntable or continuous recording and direct playback are required, a second identical Unit 539 Recorder can be connected to a Unit 540 or 295 Amplifier-Equalizer.

SOUND EQUIPMENT

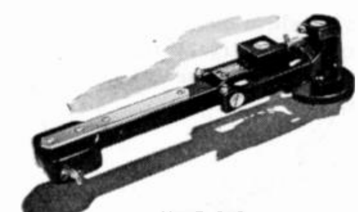
Fairchild **CAMERA AND INSTRUMENT CORPORATION**

FOR IMPROVED PERFORMANCE



UNIT 541
MAGNETIC CUTTERHEAD

Earlier FAIRCHILD portable models and many other types of recorder-playbacks will give vastly improved performance if equipped with an improved Fairchild Pickup and Cutterhead. For complete information address: 88-06 Van Wyck Boulevard, Jamaica 1, N. Y.

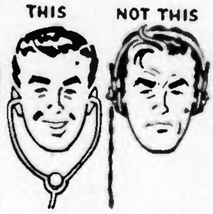


UNIT 542
LATERAL DYNAMIC PICKUP

MEMBERSHIP

(Continued from page 46A)

May, M., 4544 Hazel St., Chicago 40, Ill.
McCormick, J. D., 412 Kearny Ave., Kearny, N. J.
McLemore, J. C., 608 S. Cochran St., Los Angeles 36, Calif.
Miner, R. D., 1260 W. 66 St., Los Angeles 44, Calif.
Minton, W. C., 17 Teaneck Rd., Ridgefield Park, N. J.
Moutoux, E. A., 10 Duke St., E., Apt. 6, Kitchener, Ont., Canada
Murgatroyd, C. A., 202 Dickson St., San Antonio 4, Texas
Nelson, E. P., 2253 University Ave., New York 53, N. Y.
Nicodemus, F. E., 642 Pleasant St., Bellmont 78, Mass.
Nyswander, R. E., 1 Crawford St., Apt. 2, Cambridge 39, Mass.
Olson, A. E., 3831 N. Fremont St., Chicago 13, Ill.
Opie, A., 345 Wyoming Ave., South Orange, N. J.
Patton, A. D., 623 Cupples Rd., San Antonio 7, Texas
Peacock, M. L., 2616–94 Ave., Oakland, Calif.
Pearce, O. M., 1720 K St., Galveston, Texas
Pearson, A. B., 306½ College St., Room 208, Beaumont, Texas
Piip, A. T., Soderliden 7, Lidingo 2, Stockholm, Sweden
Pullen, W. T., Drawer 1030, Port Arthur, Texas
Reid, F. G., 110—27 St. W., Saskatoon, Sask., Canada
Reitlinger, A., 90-01—98 St. Woodhaven, L. I., N. Y.
Rowe, J. H., Moor Cottage, Bramshott Chase, Hindhead, Surrey, England
Rozen, D. A., 1040 S. Alfred St., Los Angeles 35, Calif.
Ruedisueli, R. W., 92 Hopping Ave., Staten Island 7, N. Y.
Ruis, E., 188 Loiza St., Santurce, Puerto Rico
Scheets, D. F., 8221 Schrider St., Silver Spring, Md.
Shubert, N., RFD, Lapwai, Idaho
Smith, F. W., 422 N. W. Eighth St., Portland 9, Ore.
Sorem, H., 6451 E. Michigan Ave., Jackson, Mich.
Spacer, J. P. Jr., 29 Blue-Hill Ave., Roxbury, Mass.
Spear, L. P., Postgraduate School, U. S. Naval Academy, Annapolis, Md.
Spencer, A. J., 81 Ruttan St., Port Arthur, Ont., Canada
Stanford, C. P., 109 Tacoma Rd., Oak Ridge, Tenn.
Steinmann, W. X., 26 Wibichstr., Zurich 10, Switzerland
Stilgenbauer, R. M., 6675 Franklin Ave., Hollywood 28, Calif.
Stratemeyer, C. H., Collins Radio Co., Cedar Rapids Iowa
Sutherland, L. C., 1328 Westwood Blvd., Los Angeles 24, Calif.
Tant, V. E., 250 Cooper St., Ottawa, Ont., Canada
Taylor, F. E., 143-43—41 Ave., Flushing, L. I., N. Y.
Temple, D. I., 17 Coligni Ave., Apt. 4-B, New Rochelle, N. Y.
Tennant, M. J., 158 E. Main St., Webster, N. Y.
Tobin, R. D., Jr., 2020 Nicollet Ave., Minneapolis 4, Minn.
Valko, G. A., 25 Hohtal, Baden, Aargau, Switzerland
Waag, J. P., Jr., 147-08—33 Ave., Flushing, L. I., N. Y.
Ware, L. R., 136 Appleton St., Cambridge 38, Mass.
Wiley, J. L., 1418 Lincoln St., Houston 6, Texas
Williams, J. R. L., 1328 Union St., Schenectady, N. Y.
Wood, H. C., 1032 S. Racine Ave., Chicago 7, Ill.
Yeo, R. F., 64 Marmora St., London, Ont., Canada
Young, K. W., 4 Madden Ct., Richmond, Ind.
Yonugren, A. E., 2031 New York Ave., Brooklyn 10, N. Y.



News—New Products

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

(Continued from page 60A)

• • • On Soldering Irons, by *Hexacon Electric Co.*, 161 West Clay Ave., Roselle Park 9, N. J. Bulletin No. 140.

• • • On Age of U. S. Patent Numbers, by *Invention, Inc.*, Munsey Building, Washington 4, D. C.

• • • House organ of the *Collins Radio Company*, 855 Thirty-Fifth St., Cedar Rapids, Iowa, "The Collins Signal," will shortly resume publication. The mailing list is now being compiled.

Regulated Power Supply

A light weight source of regulated voltage for general laboratory and production use has been recently announced by the Hewlett-Packard Co., Palo Alto, Cal.

It is claimed that the output of the -hp- model 710A is continuously variable from 180 to 360 volts and will remain constant to within 1% for loads from 0 to 75 ma, and for line voltage variations of ±10%.

Surplus Radio Materials Service

A new service which will make thousands of government surplus items available to radio and electronic parts buyers has been recently announced.

Illustrated lists of available items are yours for the asking by writing to the Concord Radio Corp., Surplus Div., 265 Peachtree St., Atlanta 3, Georgia.

Plant Expansions

• • • At Hicksville, L. I., by *Press Wireless, Inc.*, to move the Engineering Division, from Long Island City, N. Y.

• • • At Lewiston, Maine, by *North American Philips Co., Inc.*, to move the Wire Division from Dobbs Ferry, N. Y.

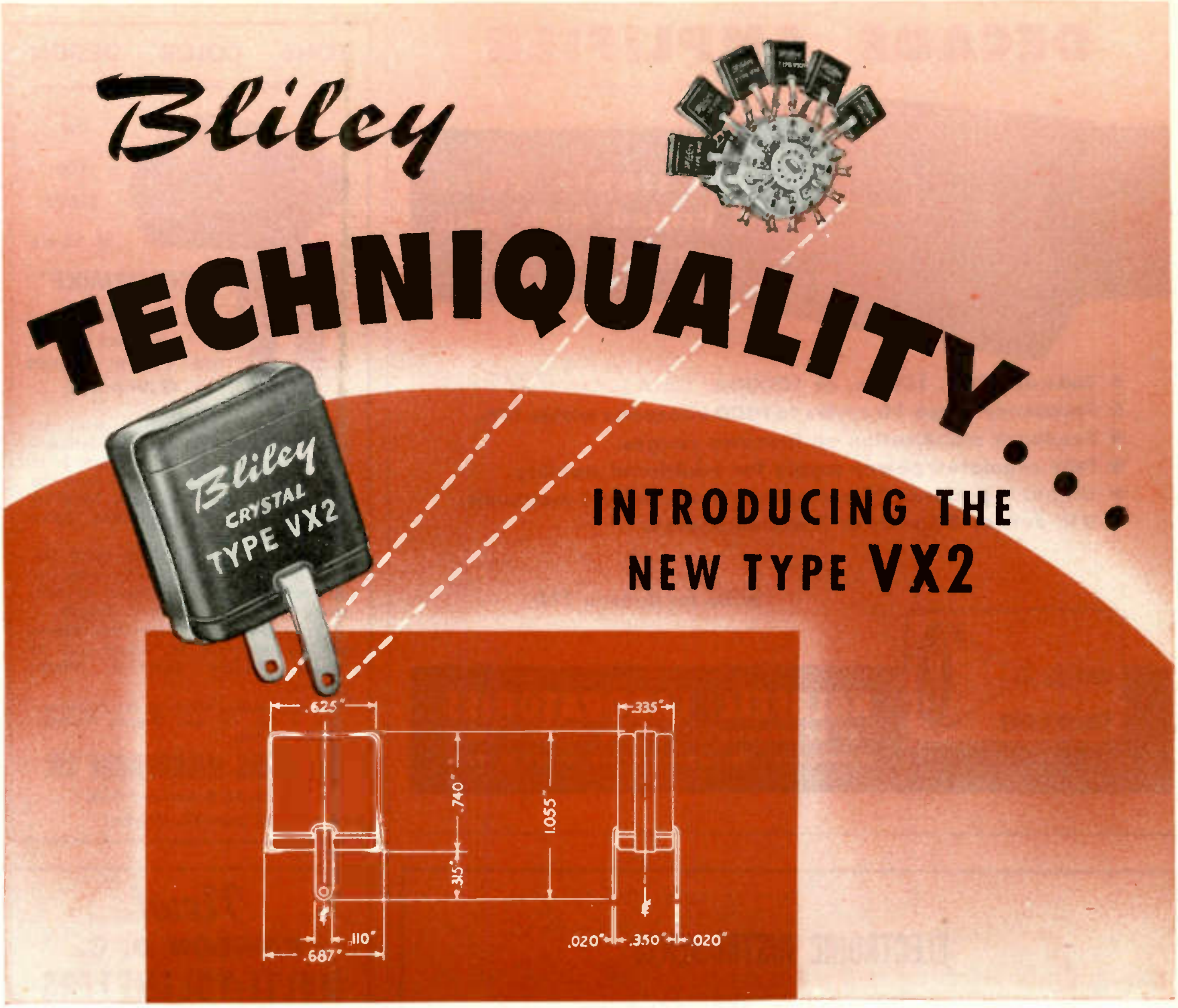
• • • At Philadelphia, Pa., by *Philco Corporation*, totaling 300,000 square feet of floor space, for the manufacture of radio and television sets.

• • • At Buchanan, Mich., by *Electro-Voice, Inc.*, their entire plant from South Bend, Ind.

• • • At Newark, N. J., by *Weston Electrical Instrument Corp.*, totaling 70,000 square feet of floor space, as a three-story engineering building.

• • • At Erie, Pa., by *Stromberg-Carlson Company*, a five-story building to manufacture FM radio-phongraphs and dial exchange telephones.

(Continued on page 68A)



Designed for use where space is at a premium

Take a look at the space saving dimensions of this new Type VX2 crystal unit. Into this compact holder, Bliley engineers have packed a quartz crystal assembly that will perform, under rugged service conditions, with more dependable accuracy than was formerly possible in a crystal many times the size of Type VX2.

This new Type VX2 unit is available for frequencies from 3000 kc to 11000 kc. Solder lugs, replacing the conventional pin type connections, permit easy mounting under chassis. For multifrequency applications a group of units may be mounted on a conventional rotary selector switch. Gasket seals assure reliable operation under adverse service conditions.

Whenever there is an important frequency control problem to be solved—make it a habit to consult Bliley engineers first. You'll find their 15 years experience, in frequency control engineering exclusively, a short cut from the experimental models to your production line.

Bliley
CRYSTALS

Communications Engineers

Here are two important Bliley Bulletins that should be in your file—

Ask for Bulletins P-27, P-31

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Consultant on Industrial Electronic Applications and Electrical Devices for Physical Measurements
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Phone MA 1243

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Radio - Frequency Measurements
Special Antenna Problems
Wideband Amplifiers and Filters
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Great Neck, New York Imperial 645

Paul D. Zottu
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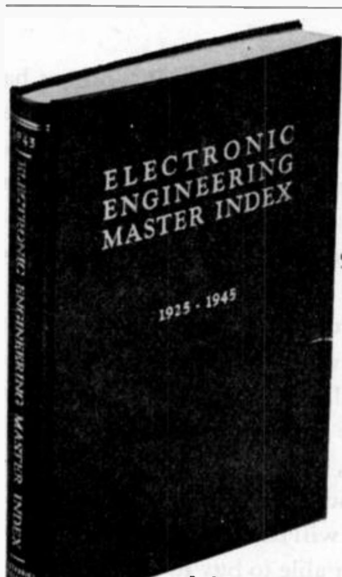
Industrial Electronics
High Frequency Dielectric and Induction Heating Applications, Equipment Selection, Equipment and Component Design, Development, Models.
272 Centre St., Newton, Mass. BIG-9240



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ELECTRONICS RESEARCH
PUBLISHING COMPANY
2 West 46 St., New York 19, N.Y.

News—New Products

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

(Continued from page 64A)

Low Cost Oscillograph

Type 274, cathode-ray oscillograph, for routine testing has been placed on the market at a low price by the Allen B. DuMont Laboratories, Inc., 2 Main Avenue, Passaic, N. J. Cabinet dimensions are 14" high, 8⅝" wide, 19⅜" deep, and weighs 35 lbs.

The linear time-base has a range of 8 to 30,000 cps. Synchronization may be from the vertical amplifier or an external signal. The vertical and horizontal amplifiers are identical and have a range from 20 to 50,000 cps.

National Radio Week

At a recent meeting of the advertising committee of the Radio Manufacturers Association and executives of the National Association of Broadcasters, it was tentatively agreed to observe National Radio Week from November 24 through 30, 1946.

FM Engineering Clinic

Plans have been tentatively made for a three-day session, starting December 2, 1946, of an FM engineering clinic devoted to FM broadcast station problems, it has been announced by Radio Engineering Laboratories, 35–54 36 Street, Long Island City, N. Y. The program will deal with FM theory, progress and operating-techniques review; actual laboratory work; and round-table discussions.

RF Induction Heaters

Two new models of induction-type electronic power generators for the precise, localized heat treating, brazing and soldering of metals are now in production according to the Engineering Products Division, Radio Corporation of America, Camden, N. J.

INDEX

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The wide variety of electrical insulating materials—each made by a recognized leader in his particular field—gives the IMC Engineer an objective view towards product improvement. His knowledge and experience qualify him to be the electrical insulation consultant on your staff. He and the IMC organization behind him are qualified and desire to:

1. Assist you in the selection of the best insulating materials for the job.
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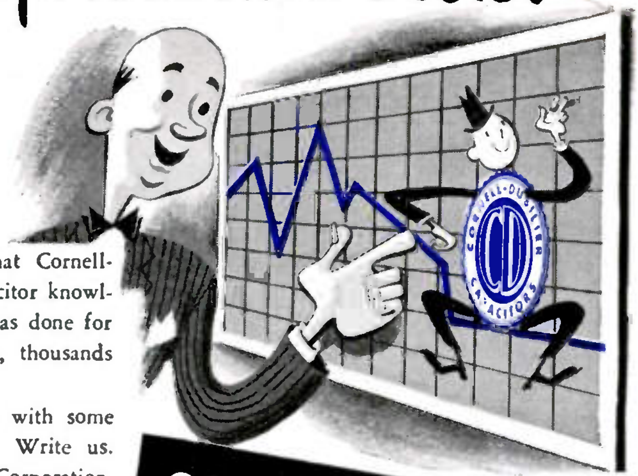
IMC PRODUCTS: Macallen Mica Products—Vartex Varnished Cloth and Tapes—Varslot Combination Slot Insulation—Fiberglas Electrical Insulation—Manning Insulating Papers and Pressboards—Dow Corning Silicones—Dieflex Varnished Tubings and Saturated Sleevings—National Hard Fibre and Fishpaper—Phenolite Bakelite—Permacel Adhesive Tapes—Asbestos Woven Tapes and Sleevings—Inmanco Cotton Tapes, Webbings, and Sleevings—Pedigree Insulating Varnishes—Wedgie Brand Wood Wedges.

"Hey, You're Sitting On My Production Costs!"



I wrote a delighted manufacturer of electrical household appliances.

We grant you, a balance sheet is a strange place for an engineer to cool his heels. But this is just another way of showing you that "specialization" and "engineering flexibility" aren't merely words we throw around at Cornell-Dubilier; they carry weight . . . much weight! The fact that Cornell-Dubilier engineers were able to let loose 100% of their brain power and experience in designing capacitors shown below is proof that Cornell-Dubilier's specialized capacitor knowledge can save you, as it has done for many other manufacturers, thousands of production dollars.

Perhaps we can help you with some special capacitor problem. Write us. Cornell-Dubilier Electric Corporation, South Plainfield, New Jersey. Five other plants in New Bedford, Providence, Worcester and Brookline.

CORNELL-DUBILIER
world's largest manufacturer of
CAPACITORS

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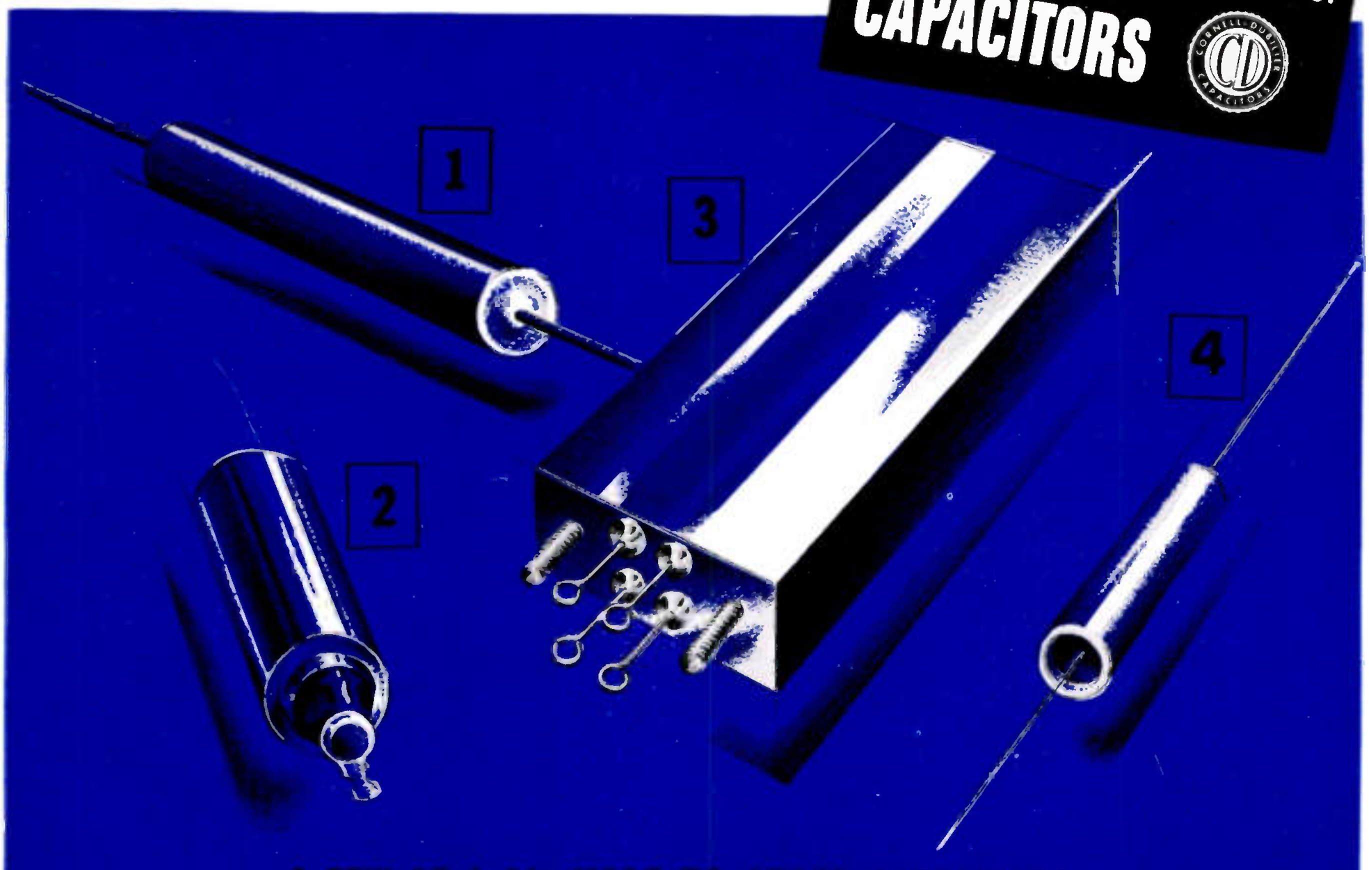

A FEW OF C-D's MADE-TO-ORDER CAPACITORS

CAPACITOR #1. Here is a capacitor designed specifically for automobile horn spark suppression. Fits into horn housing with minimum of assembly operations. Leads firmly, mechanically anchored to stand extreme vibration.

CAPACITOR #2. This capacitor was designed for high temperature application in equipment operating at 105° C. Unit is hermetically sealed and provided with glass, solder sealed terminals.

CAPACITOR #3. Built for operation with telephone relay and amplifier equipment. Construction makes for ease of assembly into parent apparatus and assures a life-time of trouble-free service.

CAPACITOR #4. Tubular paper capacitor for bypass applications in radio receivers. This unit is encased in a metal tube which is then fully insulated with a cardboard sleeve. Meets all UL requirements for non-combustible case type capacitor.