ROCEEDINGS OF THE I·R·E

AND

WAVES AND ELECTRONS

John F. Garfield, Radiation Laboratory, M.I.T.

ANTENNA OF THE EIGHTH AIR FORCE MICROWAVE EARLY WARNING AT GREY FRIARS, EAST ANGLIA, SHOWN AS IT WAS CONTROLLING THE EIGHTH AIR FORCE FIGHTER PLANES ON THE DAY OF THE DUTCH AIRBORNE INVASION

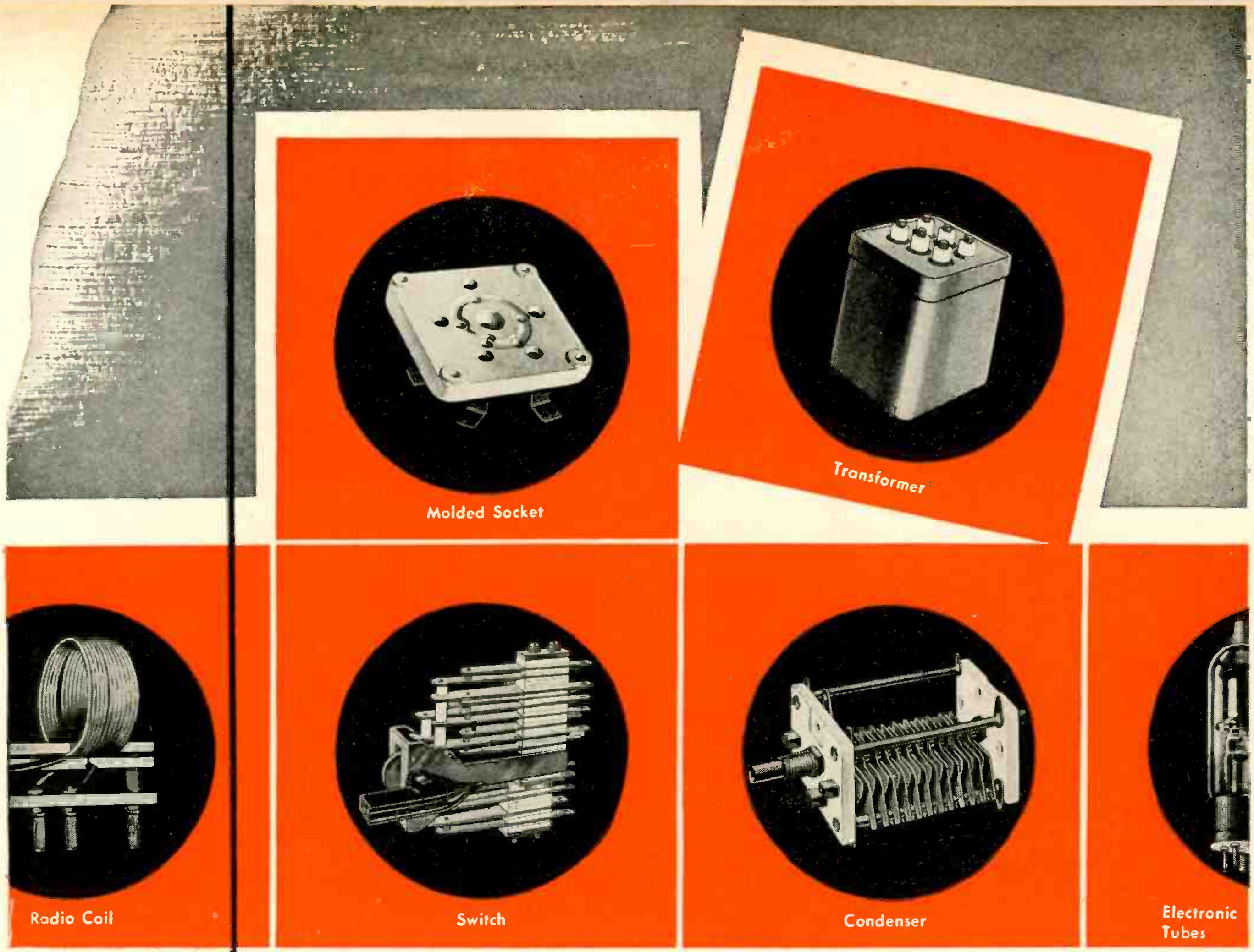
June, 1946

Volume 34 Number 6

PROCEEDINGS OF THE I.R.E.

Waves and Electrons Section

The Institute of Radio Engineers



PROCEEDINGS OF THE I.R.E. AND WAVES AND ELECTRONS, June, 1946, Vol. 34, No. 6. Published monthly in two sections by The Institute of Radio Engineers, Inc., at 450 Ahnaip St., Menasha, Wis., or 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.

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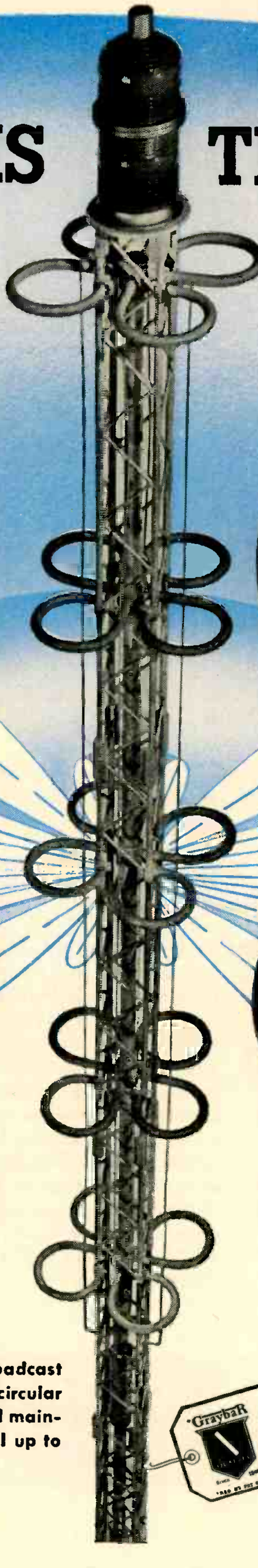
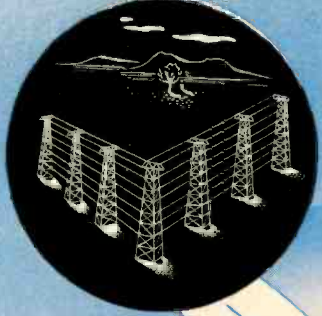
Why THIS TEAM IS



1920 Loop antenna for 400-500 meter ship-to-shore radio telephone receivers. Its design enabled earliest measurements of field strength.

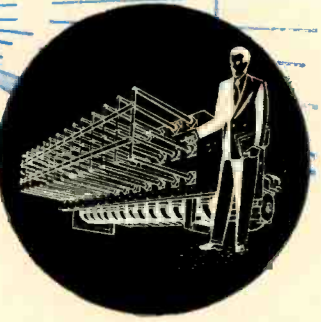


1929 Curtain antennas developed for beaming short-wave radio telephone messages to Europe and South America . . . improved commercial service.

1930 Half-wave vertical radiator, now in general use, was developed into practical form. It greatly improved signal output of broadcast stations.

1934 One of the first directional antenna arrays for broadcasting. Designed for WOR to concentrate signals in service area, eliminate radiation over ocean.

1938 Coaxial antenna for ultra high frequency communications, designed by Bell Laboratories, gave increased signal strength. Widely used in police radio systems.



1941 Polyrod radar antenna was an important war contribution . . . helped sink many Jap ships. Its exceptionally narrow beam and rapid scanning gave high accuracy to big Navy guns.

1946 New 54A CLOVER-LEAF FM broadcast antenna has high efficiency and a circular azimuth pattern; is simple to install and maintain. May be used for any power level up to and including 50 KW.

Distributed by GraybaR ELECTRIC COMPANY

Up ON ANTENNAS

As pioneers and leaders in radio, Bell Telephone Laboratories and Western Electric have been vitally concerned with the development of improved antennas for more than 30 years.

From the long-wave days of radio's youth, right through to today with its microwaves, this team has been responsible for much of the progress in antenna design.

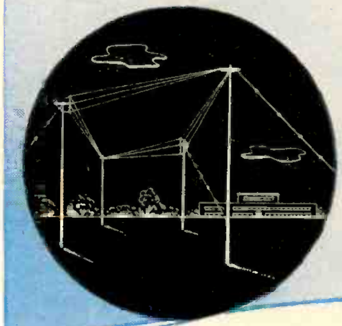
Progress based on Research

Following their long-established method of attack, Bell Laboratories scientists are continually *observing*, *investigating* and *measuring* the action of radio waves in space. Their research has covered wave lengths ranging from hundreds of meters to a fraction of a centimeter. In over a quarter-century of intensive study, they have learned how radio waves behave, day and night, under all sorts of weather conditions.

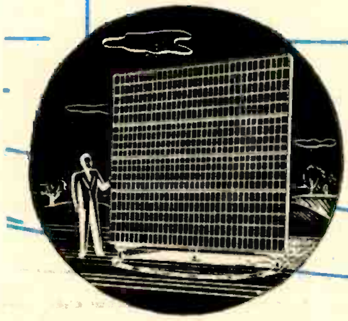
Out of this fundamental research have come such outstanding developments as the rhombic antenna, musa antenna, vertical half-wave radiator, curtain antenna, directional array, the polyrod and other improved radar antennas, the metal lens for microwaves and the new CLOVER-LEAF antenna for FM broadcasting.

What this means to YOU

Whether you are interested in AM or FM—equipment for broadcasting, point-to-point, aviation, mobile or marine use—here's the thing to remember. Every item of radio apparatus designed by Bell Laboratories and made by Western Electric is backed by just such thorough scientific research as has been given to antennas. It's designed right and made right to give you years of high quality, efficient, trouble-free service.



1930 Rhombic (diamond-shaped) antenna for 14-60 meters. It covers wide frequency range without adjustment. Still standard for this band.



1944 Metal lenses, another Bell Laboratories development, focus microwaves like light. One type has a beam width of only 0.1°—or less than that of a big searchlight.

BELL TELEPHONE LABORATORIES

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

Western Electric

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

Newest

v-h-f power triode for FM and TELEVISION

TYPE
GL-9C24
TRANSMITTING
TUBE

- **Frequency up to 220 megacycles at maximum plate input.**
- **High power output—see ratings!**
- **All the electrical characteristics of ultra-modern h-f tube design.**
- **Sturdy and COMPACT, for close side-by-side tube mounting.**
- **G-E RING-SEAL construction . . . gives generous terminal-contact areas.**

RATINGS

Filament voltage	6.3 v
Filament current	250 amp
Grid-plate transconductance	11,000 micromhos
Interelectrode capacitances:	
Grid-filament	23 micromicrofarads
Grid-plate	15 micromicrofarads
Plate-filament	0.7 micromicrofarads
Type of cooling	water and forced air
Plate ratings per tube, Class B r-f power amplifier (video service, synchronizing peak conditions):	
Max voltage	5,000 v
Max current	2 amp
Max input	10 kw
Max dissipation	5 kw
* Useful power output, typical operation (at 4,000 v and 1.7 amp, band width 5mc)	3.4 kw
Plate ratings per tube, Class C r-f power amplifier (key-down conditions without modulation):	
Max voltage	6,500 v
Max current	2 amp
Max input	12 kw
Max dissipation	5 kw
* Useful power output, typical operation (at 6,000 v and 1.3 amp)	6.4 kw

*Includes power transferred from driver to output of grounded-grid amplifier.

GENERAL ELECTRIC'S great new power tube for FM and television—Type GL-9C24—combines high power output at very-high frequencies with unexcelled advantages of design. *This is the tube you want and need,* for the power amplifier stages of new transmitters now on your drawing-boards!

In FM use, a pair of GL-9C24's, operating conservatively, will put out more than 10 kw of power. In television, broad-band tests prove that a pair easily will deliver in excess of 5 kw at synchronizing peak level.

No neutralization is required when GL-9C24's are employed in a properly designed line or cavity type of grounded-grid amplifier—the circuit to which this tube is particularly adapted. Other features: . . . Lead inductance is extremely low. All external metal parts are silver-plated, to reduce r-f losses and provide better electrical contact surfaces. Fernico metal-to-glass bonds are used throughout. Ring-seal design gives large terminal-contact areas, with correspondingly improved efficiency.

G-E tube engineers are ready to work closely with you on the application of this *new* v-h-f tube to your *new* FM and television transmitters. Phone your nearest G-E office, or write the *Electronics Department, General Electric Company, Schenectady 5, New York.*

GENERAL ELECTRIC

161-E9-8850

FIRST AND GREATEST NAME IN ELECTRONICS

Receiving Diversity Tone Keyer

Designed, Engineered

and Built to Work

for the World's Most

Critical Employer . . .

The International Press

MODEL R-626

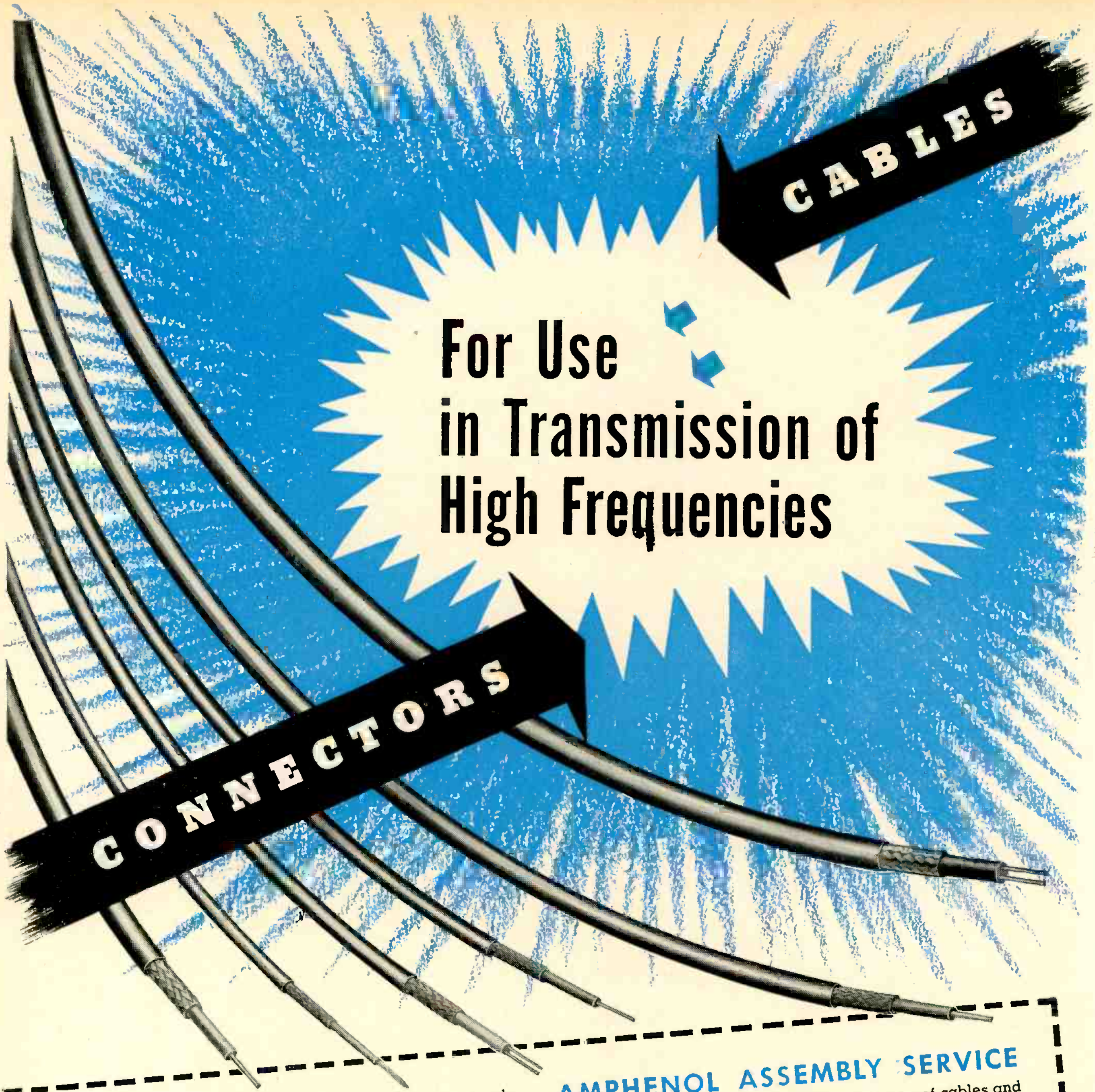
It's to the credit of Press Wireless that its international communications systems and their components have for a decade and a half stood up to the task of delivering the tens-of-thousands of words of vital, high speed radio communications traffic daily demanded by the press of the world.

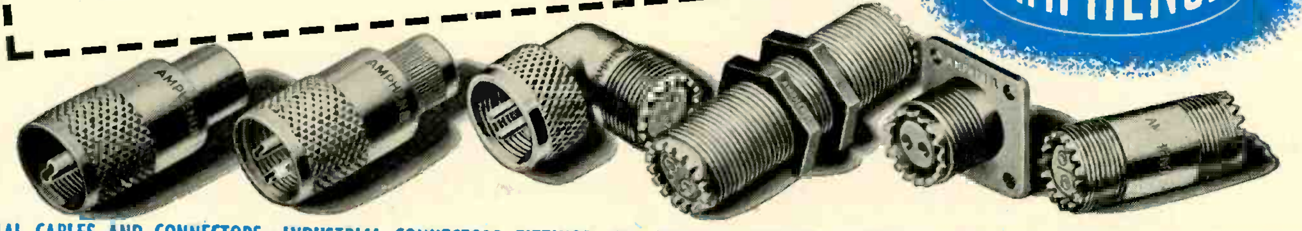
The R-626 Tone Keyer, like all other Press Wireless developed equipment, has been carefully designed by experienced engineers; the men who for years have been charged with the responsibility of planning, installing and operating the vast array of equipment which makes up the Press Wireless international radio press circuits.

R-626 RECEIVING DIVERSITY TONE KEYER CHARACTERISTICS

- **Connections for diversity receiver operation**
- **Multiple fixed-frequency receiving feature**
- **High keying speeds better than 1000 w p m**
- **Constant amplitude keyed audio output to + 20 vu**
- **Input requires minimum of only 1 volt from 2nd detector of one *or more* receivers.**
- **Output selectable for anyone of 6 standard filter tones**
- **Reduced keying bias with front panel "shaper" control**
- **I-F Monitor circuit for precise receiver i-f adjustment**
- **Built-in, 110 volt, 50/60 cycle power supply**
- **Standard 19-inch rack mounting**

PRESS WIRELESS MANUFACTURING
CORPORATION
Executive Offices: 38-01 35th AVENUE, LONG ISLAND CITY 1, NEW YORK


CABLES
For Use
in Transmission of
High Frequencies
CONNECTORS

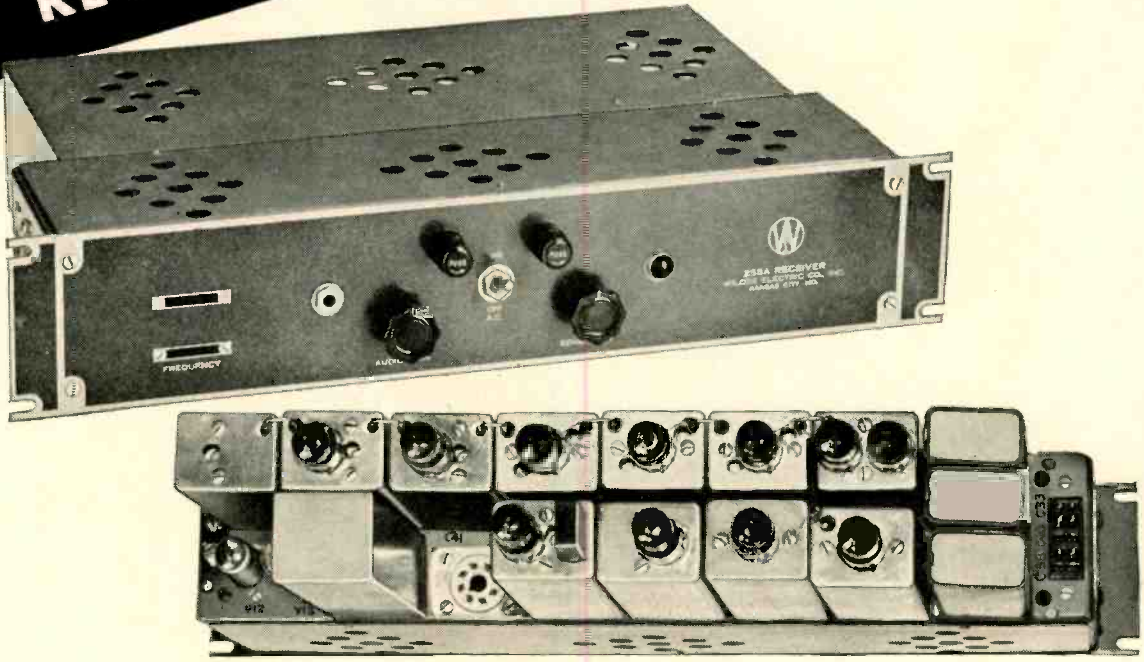


THE WILCOX TYPE 255A RECEIVER

A new fixed frequency receiver to meet the present and future requirements of aeronautical ground-air, or point-to-point radio communications.

With increased traffic and new services taxing the already over-crowded 2-20 Mc communication frequencies, the Wilcox Electric Co. Type 255A Receiver has been especially engineered to minimize adjacent channel interference, and to maintain good intelligibility on telephone reception.

The Type 255A occupies only 3½ inches of rack space, making it readily adaptable to the replacement of existing receivers.



- Input Impedance: 70 ohms.
- Output Impedance: 500 ohms, center-tapped.
- Power. 110 V.A.C., 50-60 cycles, 60 watts.
- Output Power: Choice of 50 milliwatts or 1.25 watts.
- Sensitivity: 1 microvolt at 2/1 SN ratio.
- Spurious Frequency Response: 80 D.B.
- A.V.C.: 3 DB variation from 10 microvolts to 1.5 volts.
- Selectivity: 2X—2 Kc. wide.
  10X—4 Kc. wide.
  100X—7 Kc. wide.
  1000X—11 Kc. wide
- Size: 3½" H. x 19" W. x 11½" D.

Detailed information on request.

Use of miniature tubes permits the building of each stage of the receiver complete within its own shield can, which in turn, plugs into an octal tube socket on the chassis.

Thus, each stage is instantly removable for maintenance, and may be checked in a test set similar to those used for vacuum tubes. Maintenance may then be accomplished on the bench, or a spare stage plugged in, and the stage returned to a maintenance base.

WILCOX ELECTRIC COMPANY, INC.

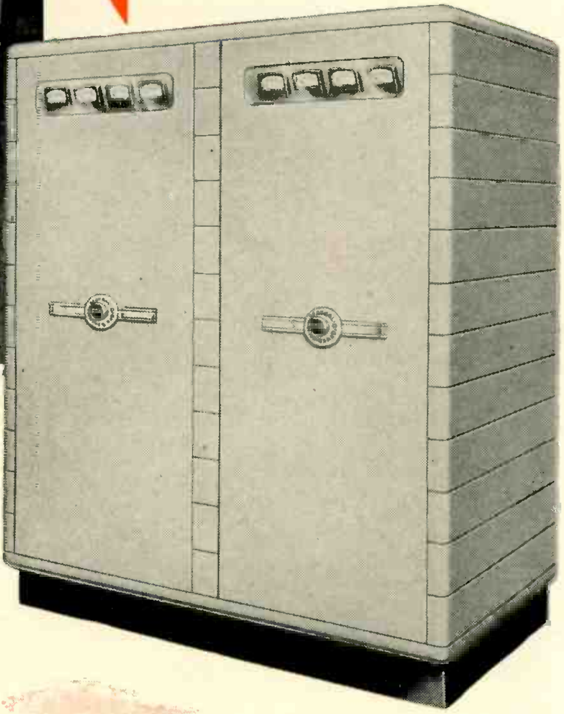
Manufacturers of Radio Equipment

FOURTEENTH AND CHESTNUT
KANSAS CITY, MISSOURI

FEDERAL's

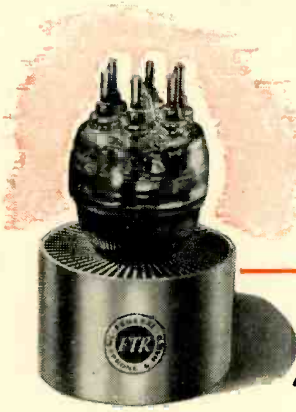
. . . and

Here's Federal's 1 Kw FM transmitter that stole the show at the sixth annual Broadcast Engineering Conference at Ohio State University. A group of engineers are shown examining the equipment in actual operation at the conference.



Federal Features for Better FM

- ✓ Federal's new "FREQUEMATIC" FM modulator—a radically improved type of modulator-oscillator unit—gives FM transmission outstanding fidelity and mean-carrier stability, with unsurpassed dependability and economy.
- ✓ By means of simple all-electronic circuits, "FREQUEMATIC" maintains the center-frequency stability within a tolerance of plus or minus one thousandth of one per cent of the assigned value—only *half* of the present FCC tolerance requirement.
- ✓ Remarkable noise-level reductions resulted in an actual measured signal-to-noise ratio of 5600 to 1—a level so low that Federal had to build special test equipment for its measurement.
- ✓ Undistorted modulation of all audio signals between 50 and 15000 cycles is maintained, even when the transmitter is overmodulated as much as three hundred per cent by transient passages.
- ✓ This outstanding performance is obtained with simple circuits and standard receiver tubes, and the equipment depends mainly on resistances and capacitances for critical and non-critical functions.
- ✓ Another feature—of special interest to all broadcasters—is the extreme ease of initial alignment and operational maintenance. The unit can be completely tuned in a matter of minutes, as only two tuning operations are necessary. There are no tuned circuits in the crystal oscillator or frequency divider networks.



New high-efficiency, air-cooled and water-cooled tubes, developed by Federal, are employed in the power amplifier stages of the transmitter, contributing to long life, stable operation and low noise level.

Federal

FM STEALS THE SHOW

orders are being filled *now!*

1, 3, 10, 20, 50 Kw FM TRANSMITTERS
featuring the new "FREQUEMATIC"* MODULATOR

FCC GIVES GREEN LIGHT TO FM

COLUMBUS, OHIO. When the Federal Communications Commission started issuing engineering authority for new high-power FM broadcast stations, it acted wisely in the national interest both from the standpoint of the radio industry and the listening public, it was declared by Norman E. Wunderlich, executive sales director, Federal Telephone and Radio Corporation, in a statement here while attending the sixth annual Broadcast Engineering Conference held at the Ohio State University.

Not only has the FCC, by its action, set the industry in motion for the manufacture of frequency modulation transmitting equipment and receivers, but it has assured the listening public of the finest of high-fidelity reception, Mr. Wunderlich stated. He added that the Commission should be warmly ap-

Federal's display of FM transmitting equipment, in actual operation at the sixth annual Broadcast Engineering Conference, created a real sensation among the country's foremost broadcast engineers. The new "FREQUEMATIC" modulator, an exclusive feature of Federal's 1, 3, 10, 20, 50 kw transmitters, made big news—exceeding the exacting requirements of the FCC Standards of Good Engineering Practice on every technical point. Of outstanding importance, too, is the fact that this new FM equipment is in actual production now!

Federal is ready to provide your new FM station with the finest transmission equipment available—complete in every detail, from microphone to transmitting tower. This outstanding "one-source" service means completely matched components for the entire system—all precision engineered, all of highest quality, all designed to work together as a single, perfected and coordinated FM system.

Federal gives complete service, too. Federal will provide a factory-trained radio engineer to supervise the installation, tune up the equipment, and to instruct your personnel in its operation and maintenance—all without extra charge. Federal will also assist in obtaining CPA approval for any new buildings or construction work required for the FM transmitter equipment.

For complete information, write: Federal Telephone and Radio Corporation, Newark 1, New Jersey.

*Trade Mark

Telephone and Radio Corporation

AN IT&T ASSOCIATE

FEDERAL TELEPHONE & RADIO FTR

Export Distributor:
International Standard Electric Corporation

Newark 1, New Jersey

Centralab

CRL

The Mark of QUALITY

THE initials "CRL" in the diamond represent the research-laboratory and technical manufacturing facilities of Centralab . . . . a name outstanding for quality, precision and new developments in the field of radio and electronics.

Always Specify Centralab.

CRL

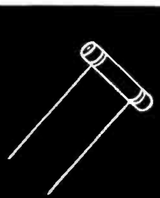
Centralab

Division of GLOBE-UNION INC., Milwaukee

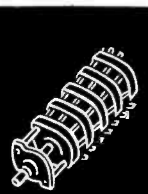
PRODUCERS OF

Ceramic Trimmers
Bulletin 695

Variable Resistors
Bulletin 697



Tubular Ceramic
Capacitors
Bulletins 630 and 586



Selector Switches
Bulletin 722

Ceramic High Voltage Capacitors
Bulletin 814

MAKING TUBES IS EASY *If* YOU KNOW HOW!

This standardized Hytron production tester is composed of three units: preheater, characteristics tester, noise tester. To permit a better view of the equipment, only one of three operators is shown.

HOW THE HYTRON 12SK7GT IS QUALITY CHECKED

Test	100% Production Test	Central Inspection Sampling	Quality Laboratory Sampling	100% Test at Packing
Shorts	x	x		x
Base shell connection	x	x		
Heater current	x	x	x	
Plate current	x	x	x	
Screen current	x	x	x	
Grid current	x	x	x	
Transconductance	x	x	x	
Suppressor action	x	x	x	
Emission	x	x	x	
Heater-cathode leakage	x	x	x	
R-f noise	x	x	x	
Transconductance cutoff			x	
Vibration			x	
Insulation resistance			x	
Input capacitance			x	
Output capacitance			x	
Grid-plate capacitance			x	
Grid emission			x	
Immersion (basing cement)			x	
Life			x	
Overall length	x		x	
Mechanical*	x	x	x	x

*Mechanical tests are covered by a multipage specification. Typical inspection is conducted visually and/or by gages for the following: pin solder, etching, getter flash, diameter, base-bulb alignment, bent base pins, glass defects, and rigidity of internal elements, bases, and base pins.

AGAIN HYTRON'S LONG EXPERIENCE GIVES YOU THE BEST...

Extreme accuracy and flexibility of this Hytron master test station particularly fit it for quality control.

FOR your protection Hytron tubes are quadruple-checked. On the production floor, each tube is first tested for significant characteristics. In the central inspection department, a random sampling is next taken for statistical control of the production testing—to assure quality within acceptance limits. Failure at this point demands 100% retest.

Daily a smaller random sampling is subjected to a searching design check of characteristics such as interelectrode capacitances, grid emission, and transconductance cutoff. These characteristics can be controlled by the smaller sampling, and their testing requires laboratory precision. Simultaneously production tests are again repeated for further statistical control. Again failure to meet acceptance limits demands 100% retest—even for design characteristics not production-tested. Finally each tube is once more short-tested and mechanically inspected just before packing.

This painstaking quadruple-checking ensures that specification failures of tubes actually shipped will be a practically irreducible minimum. When you buy a Hytron tube, you can be certain that every ounce of Hytron know-how on quality control—reinforced by wartime experience—has been in there punching to give you only the best.

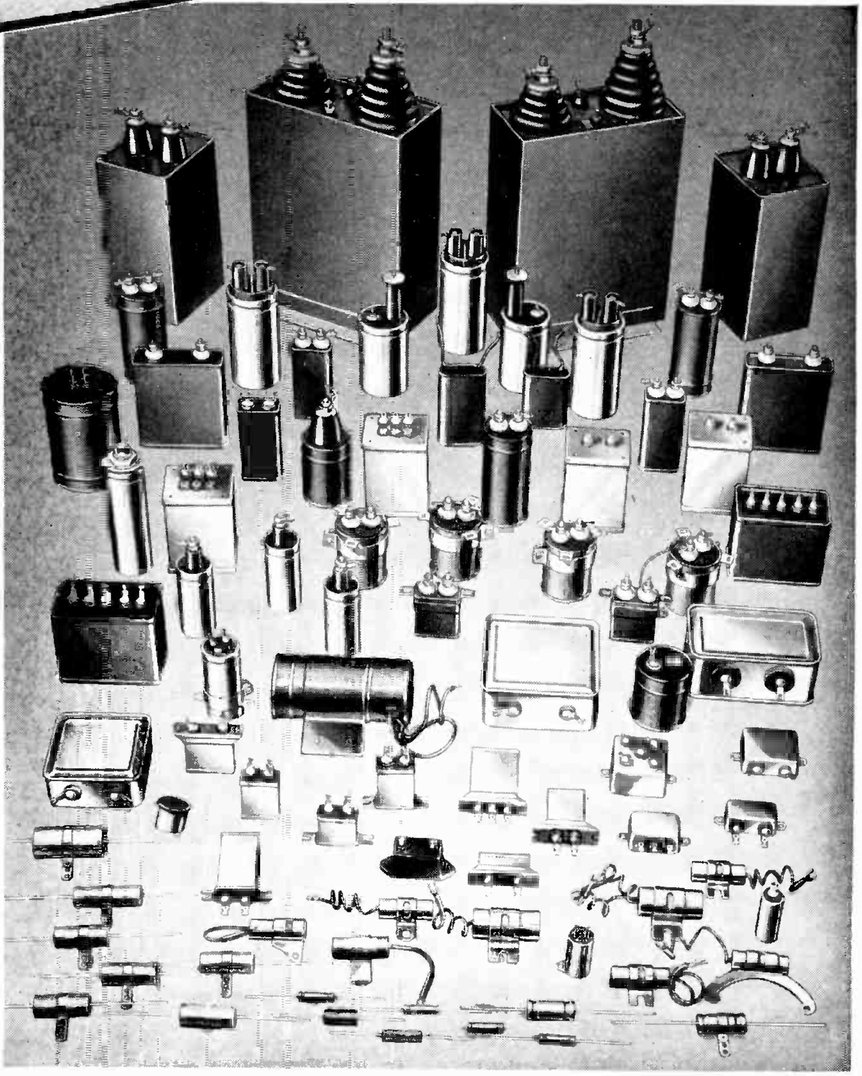
OLDEST MANUFACTURER SPECIALIZING IN RADIO RECEIVING TUBES

HYTRON

RADIO AND ELECTRONICS CORP.

MAIN OFFICE: SALEM, MASSACHUSETTS

A TYPE FOR *Every* APPLICATION OIL-FILLED CAPACITORS



- Functionally fitted to given application—that's the keynote of the extensive Aerovox oil-filled capacitor line. A plentiful selection of containers, mountings, terminals, sizes and impregnants, assures virtually custom-built capacitors with guaranteed performance.

Aerovox offers both Hyvol and Hyvol-M (mineral oil) liquid impregnants. For applications subjected to wide temperature variations, and where weight and size are important, Hyvol is recommended. Hyvol capacitors are considerably more constant with temperature variations than are those with other impregnating materials of the same specific inductive capacity, showing no capacitance drop until temperatures of −20° F. (−29° C.) are reached. At −40° F. (−40° C.) the maximum capacitance drop that may be expected is of the order of 5 to 10%.

Hyvol-M (mineral oil) capacitors have an exceptionally flat temperature coefficient of capacitance curve but approximately 35% greater bulk and corresponding weight which usually rules them out in favor of Hyvol.

At any rate, Aerovox offers both Hyvol and mineral oil capacitors, as well as wax-impregnated units for limited service—along with that wide choice of containers, mountings, terminals—to meet your exact needs.

- **NEW CATALOG** lists the exceptionally wide selection of Aerovox oil capacitors, as well as other types. Write on business letterhead for registered copy available only to engineers, designers, electronic maintenance men, manufacturers of equipment, and executives.

AEROVOX capacitors

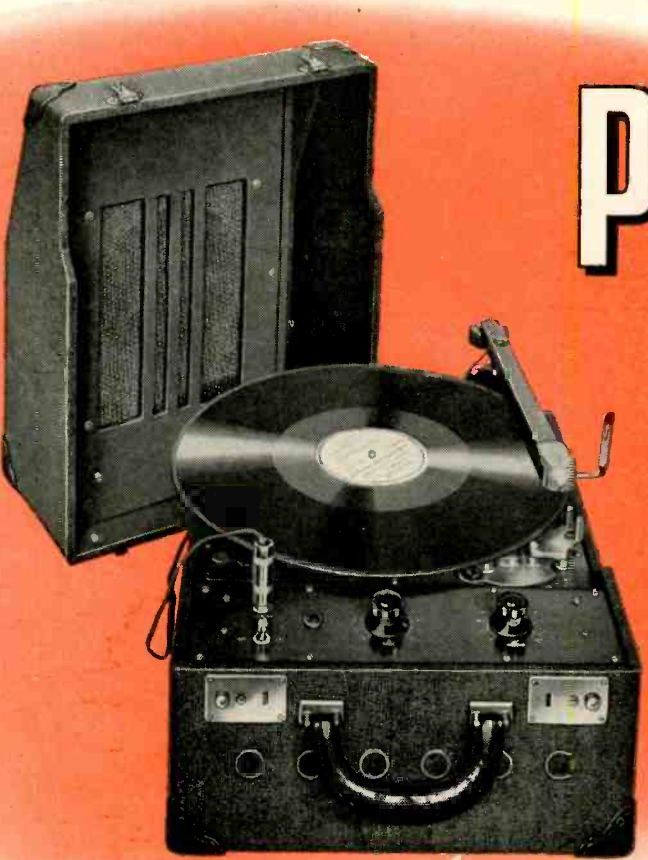
FOR RADIO-ELECTRONIC AND INDUSTRIAL APPLICATIONS

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.

ANSWERING THE DEMAND FOR "Something Better"



PRESTO
MODEL "L"

A *better* portable playback—compact, easy to carry, simple to set up. The remarkably clear, wide range of reproduction—far superior to what is ordinarily expected of a portable playback—makes it a favorite with broadcasting stations and advertising agencies who demand top performance in demonstrating recorded programs to prospective clients.

Model L plays 6 to 16″ records, 78 or 33⅓ R.P.M., on a 12″ rim-driven turntable. Standard equipment includes high quality 16″ pickup on a swivel mounting which folds into a case when not in use, four stage amplifier, 8″ loudspeaker with 20′ extension cable, and a Presto Transcriptone semi-permanent playing needle. For use on 110 volts AC only.

The complete equipment, in an attractive grey carrying case, weighs only 46 lbs.

PRESTO
RECORDING CORPORATION
242 West 55th Street, New York 19, N. Y.
WALTER P. DOWNS, LTD., in Canada

WORLD'S LARGEST MANUFACTURER OF INSTANTANEOUS SOUND RECORDING EQUIPMENT

The Answer to Television and Other High-Voltage Resistor Applications...

10,000 VOLTS BREAKDOWN

from STANDARD Sprague Koolohm Resistor to Ground

Completely insulated surface

Standard Sprague Koolohm Wire Wound Resistors have the high insulation resistance to ground which you need for television and other applications where high voltages are involved—*10,000 volts from the surface of their sturdy ceramic jackets to their resistance elements.* Mount them anywhere without fear of voltage breakdown!

In addition, Koolohms give you the advantages of higher resistances in smaller physical sizes; easier mounting; use at full wattage ratings; and overall tropicalized protection against the most severely humid conditions. Write for Catalog 10EA.

SPRAGUE ELECTRIC CO., Resistor Division, North Adams, Mass.

SPRAGUE KOOLOHMS

TRADEMARK REGISTERED U.S. PAT. OFF.

The Greatest Wire-Wound Resistor Development in 20 Years

ALL ABOUT THE NEW "EVEREADY" "A-B" PORTABLE BATTERY FOR 1.4 VOLT RECEIVERS

THIS IS THE FIRST "A-B" portable battery pack to include a "B" section constructed on the basis of National Carbon Company's exclusive flat-cell principle. With this construction, you get longer life than that available from batteries of similar size using round or "can" type cells.

This new battery, the No. 754, is a 9 volt-90 volt pack. Drawing shows the overall dimensions, socket arrangement, and socket location. The cell content and service life for the No. 754 pack are the same as for the popular pre-war battery complement consisting of 2 No. 746 4½ volt "A" batteries and 2 No. 482 45 volt "Eveready" "B" batteries.

SPECIFICATIONS...

WEIGHT .... 6½ lbs.

DIMENSIONS .... Drawing shows maximum dimensions with tolerances as indicated.

SOCKET .... 7½V — 9V — 90V R.M.A. Standard.

CELLS—"A" SECTION .... 6 "G" size cells connected in series with tap at 7½ volts.

"B" SECTION .... 60 No. 165 flat type cells connected in series.

VOLTAGE TAPS .... — A, + 7½ A, + 9 A, — B, + 90 B.

MATCHING PLUG FOR SOCKET... Cinch Mfg. Co. No. 2901, or equivalent, provides connection to — A, + 9 A, — B, + 90 B. Plugs including connection to + 7½ A have not been announced as yet.

CIRCUIT APPLICATION...

The "A" section provides radio receiver designers with maximum flexibility in choice of tube complements. Using series connected tubes with filaments rated at 50 m.a. at 1.4 volts or 50 m.a. at 2.8 volts, at least seven different circuits are suggested. Table 1 is presented to illustrate filament combinations that might be used with the No. 754 pack. One of the seven suggested combinations should provide the designer with his particular requirements insofar as balance between radio frequency sensitivity and power output is concerned.

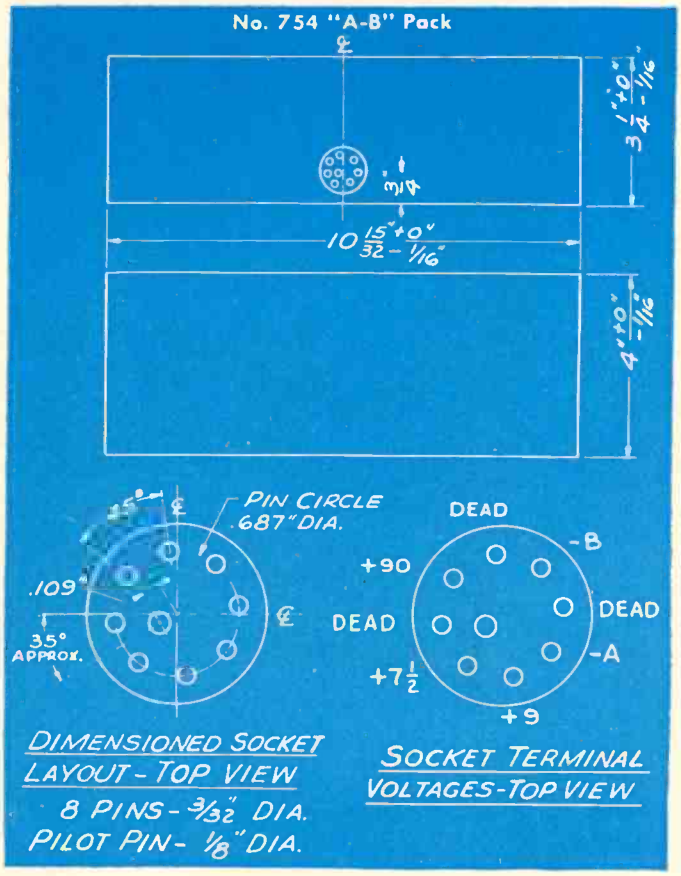
TABLE 1

TUBE FUNCTION	VACUUM TUBE FILAMENT COMBINATIONS						
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
R. F. Amplifier	1.5	1.5	—	—	1.5	—	—
First Detector	1.5	1.5	1.5	1.5	1.5	1.5	1.5
I. F. Amplifier	1.5	1.5	1.5	3.0	1.5	1.5	1.5
I. F. Amplifier	—	1.5	1.5	—	—	—	1.5
Second Detector	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Audio Output	3.0	1.5	3.0	3.0	1.5	3.0	1.5
Total "A" Voltage	9.0	9.0	9.0	9.0	7.5	7.5	7.5

SERVICE ESTIMATES...

It is impossible to predict how long batteries will last in the user's hands. Fairly accurate service estimates can be established, however, if initial current drain, hours of use per day, and end point voltage are specified. Assuming an operating schedule of four hours per day, Table 2 has been calculated to provide designers with sufficient information to indicate the magnitude of allowable "B" drain that will result in balanced "A" and "B" life. It is good engineering practice to aim at somewhat longer "A" life than "B" life. This will insure most economical operations since the "B" section of "A-B" packs is the more expensive section, and it is in the user's interest to take full advantage of the available "B" voltage.

No. 754 "A-B" Pack



DIMENSIONED SOCKET LAYOUT - TOP VIEW

8 PINS - 3/32" DIA.
PILOT PIN - 1/8" DIA.

SOCKET TERMINAL VOLTAGES - TOP VIEW

TABLE 2

SERVICE ESTIMATES—No. 754 "A-B" PACK—USED FOUR HOURS PER DAY			
INITIAL "A" DRAIN	SERVICE TO*		
	6.6 Volts	6.0 Volts	
50 m.a.	200 Hours	225 Hours	
INITIAL "B" DRAIN	SERVICE TO		
	68 Volts	60 Volts	48 Volts
10 m.a.	210 Hours	260 Hours	330 Hours
12 m.a.	160 "	200 "	260 "
15 m.a.	120 "	150 "	200 "

* To 5.5 volts and 5.0 volts, respectively, for 7.5 volt tap.

Most portable radio receivers maintain adequate sensitivity, oscillator stability, and power output over a "B" voltage range from 90 to 60 volts. In the best designs, the "B" battery is usable down to 48 volts.

NEED ANY HELP? Engineers at National Carbon will be glad to consult with you on any battery problem. Write today.

NATIONAL CARBON COMPANY, INC.

30 East 42nd Street, New York 17, N. Y.
UNIT OF UNION CARBIDE AND CARBON CORPORATION
UCC

EVEREADY
TRADE-MARKS
MINI-MAX

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

WATCH FOR IT!

DU MONT'S *new* 5-INCH OSCILLOGRAPH

The Type 274

Designed to meet the demand for an inexpensive general-purpose instrument

COMPARES FREQUENCIES • ANALYZES PERFORMANCE • SHOWS CIRCUIT FUNCTIONS

In engineering the new Du Mont Type 274 Oscillograph, the emphasis has been on "quality at a price" —and not price alone. The result: the finest laboratory instrument ever offered for less than one hundred dollars. Available soon—and *it's worth waiting for!*

only
$$99^{50}$$

© ALLEN B. DU MONT LABORATORIES, INC

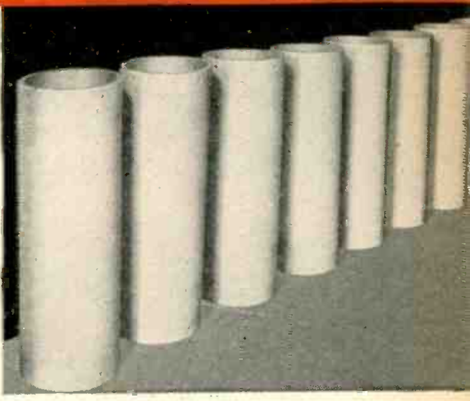
DUMONT *Precision Electronics & Television*

ALLEN B. DUMONT LABORATORIES, INC., PASSAIC, NEW JERSEY • CABLE ADDRESS: ALBEEDU, PASSAIC, N. J., U. S. A.

One or one million pieces, big or little, your best bet on technical ceramics is American Lava Corporation. For small quantities the experimental department is geared for prompt service. For large quantities you command special techniques, equipment and experience found only at American Lava Corporation.

Your request will bring property charts which give physical characteristics of the more frequently used AlSiMag compositions. If your requirement demands special or unusual characteristics, the developmental laboratory may find exactly those characteristics in its research records, or develop them quickly for you.

ALSIMAG
TRADE MARK REGISTERED U.S. PATENT OFFICE



These large, thin walled, coil forms (machined to close tolerances) are an example of American Lava Corporation craftsmanship in technical ceramics.

AMERICAN LAVA CORPORATION
CHATTANOOGA 5, TENNESSEE
43RD YEAR OF CERAMIC LEADERSHIP

ARMY NAVY

Original Award July 27, 1942
Second Award February 13, 1943
Third Award September 25, 1943
Fourth Award May 27, 1944
Fifth Award December 2, 1944

ENGINEERING SERVICE OFFICES:
ST. LOUIS, Mo., 1123 Washington Ave., Tel: Garfield 4959 • NEWARK, N. J., 1013 Wiss Bldg., Tel: Mitchell 2-8159
CAMBRIDGE, Mass., 38-B Brattle St., Tel: Kirkland 4498 • CHICAGO, 9 S. Clinton St., Tel: Central 1721
SAN FRANCISCO, 163 Second St., Tel: Douglas 2464 • LOS ANGELES, 324 N. San Pedro St., Tel: Mutual 9076

AMERTRAN TRANSFORMERS
"Take a Bow" in the New, Compact
PRESS WIRELESS TRANSMITTERS

THE new series Press Wireless Transmitters are trim, powerful, and clean as a hound's tooth. This batch is for Naval use (40 to 50 K.W.) built by Press Wireless Manufacturing Corporation at their Hicksville, Long Island factory. As the photos prove, AmerTran transformers and reactors sort of "steal the show" in these units. There's a reason. Press Wireless, Inc., the communications part of the Press Wireless organization, have been using AmerTrans for many years — in the powerful stations they operate for world-wide radio coverage. They like the characteristics and endurance of AmerTrans, and are kind enough to say so.

AmerTran Transformers are designed by authorities in electronic energy transformation. They are built in a plant devoted exclusively to the production of transformers and allied products. The entire AmerTran organization is available to help you get the most up-to-date, efficient performance for your transformer dollar. That is why AmerTran products are built-in components in the best-known communications and industrial-electronic assemblies now in operation.

Bulletin "G" shows the wide scope of AmerTran products. We'll be glad to send you a copy.

AMERICAN TRANSFORMER CO.

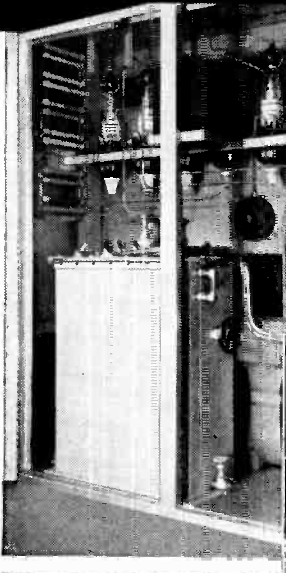
178 EMMET ST., NEWARK 5, N. J.

Pioneer Manufacturers of Transformers, Reactors and Rectifiers for Electronics and Power Transmission

AMERTRAN

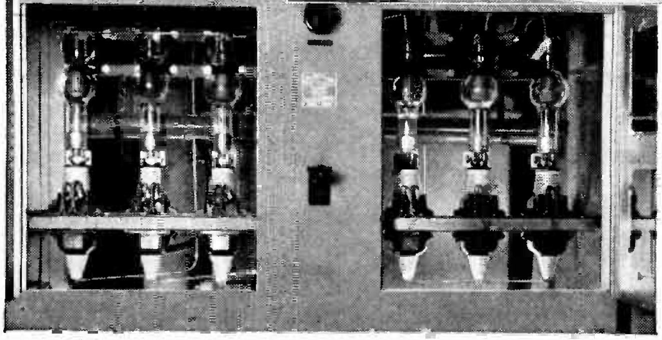
REG U S PAT OFF

MANUFACTURING SINCE 1901 AT NEWARK, N. J.

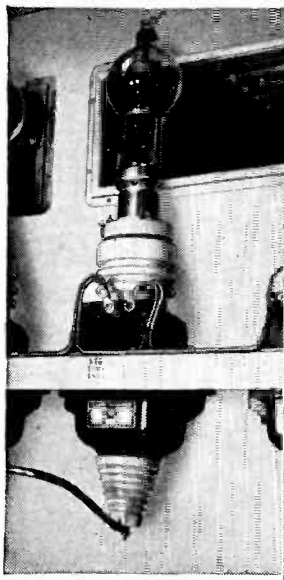


Rear of 40 KW rectifier section. AmerTran "WS" Filament transformers on upper rack. AmerTran high voltage Plate Transformer in tank at left.

Final amplifier power unit—50 K.W., using AmerTran Transmitter Components throughout.

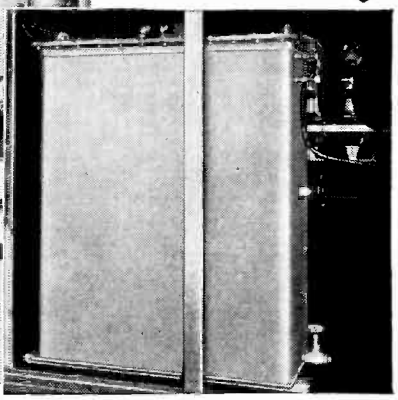


Front panel view, rectifier section, showing AmerTran Filament Transformers.



An Amer-Tran development—The Type "WS" integral Filament Transformer. Used by leading transmitter manufacturers. Short leads, space-saving design.

AmerTran 8,000 V. Plate Transformer. "WS" Filament Transformers visible at right.



The Franklin Airloop Corp., 175 Varick St., New York 14, N. Y., makes this unique antenna to set manufacturers' specifications.

IT is Revere copper that makes possible the unusual Franklin Airloop antenna. This is die-stamped out of .005″ sheet, a single operation on automatic machines forming the loop and locking it into the backboard. The result is superior ruggedness, less distributed capacity, higher "Q," and lower cost.

Thus copper once again proves that its unique qualities make it "The Metal of Invention." Easy workability, high electrical and heat conductivity, corrosion resistance, availability in a variety of tempers and in sheet, strip, plate, bar and rod—copper by Revere serves the radio industry in many different ways.

Revere also offers copper alloys, aluminum and magnesium, and electric welded steel tube. Selection of the proper metal or alloy may at times be a matter for careful study; Revere is always glad to cooperate with engineers, designers and production men in working out the most economical and efficient applications.

REVERE PRODUCTS INCLUDE

Copper and Copper Alloys in sheet and plate, rolls and strip, rod and bar, tube and pipe, extruded shapes, forgings.

Aluminum Alloys in tubing, extruded shapes, forgings.

Magnesium Alloys in sheet and plate, rod and bar, tubing, extruded shapes, forgings.

Electric Welded Steel Tube in straight lengths or semi-fabricated to your designs.

REVERE

COPPER AND BRASS INCORPORATED
Founded by Paul Revere in 1801
230 Park Avenue, New York 17, New York
Mills: Baltimore, Md.; Chicago, Ill.; Detroit, Mich.; New Bedford, Mass.; Rome, N. Y.
Sales Offices in Principal Cities, Distributors Everywhere.

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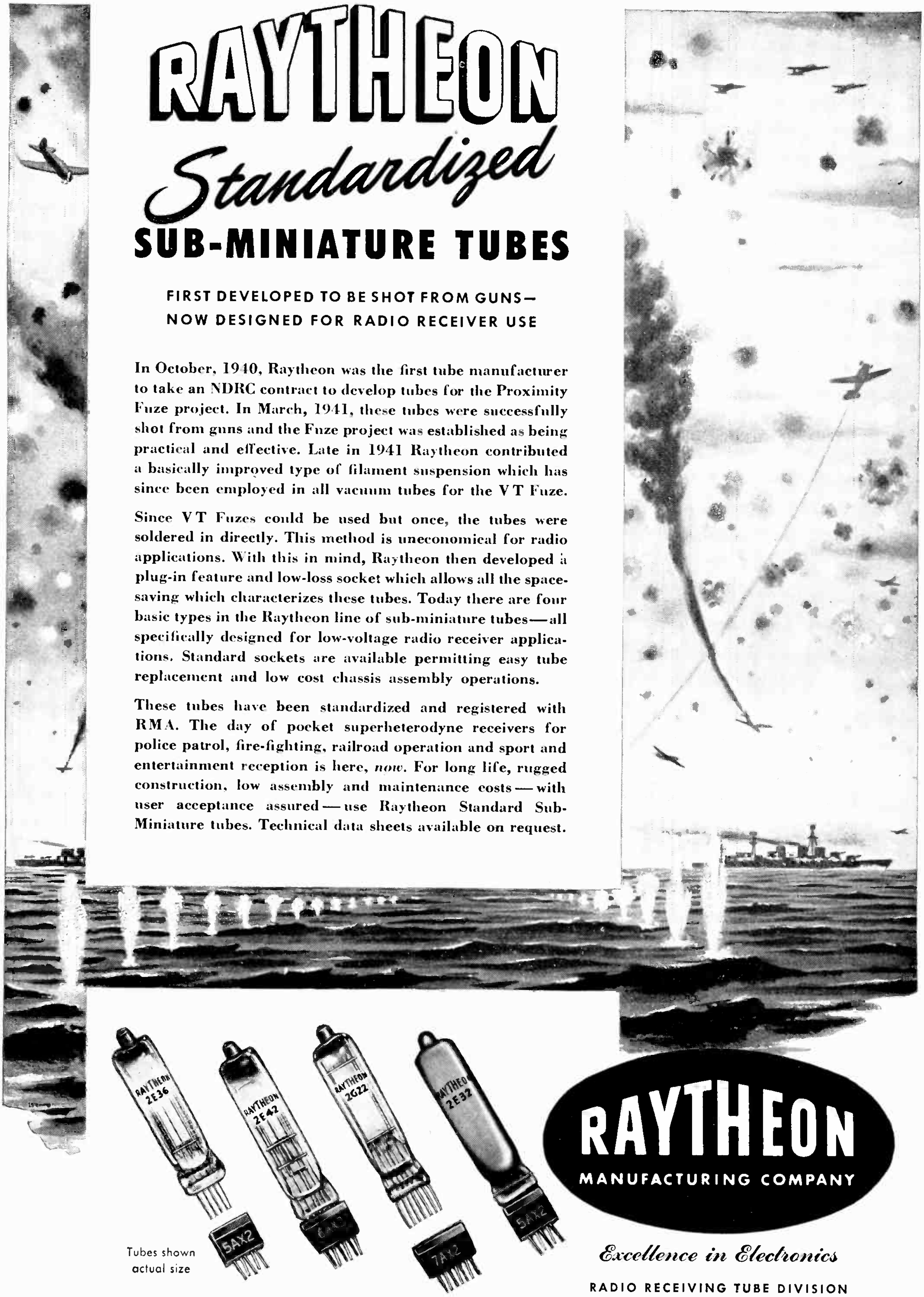
Listen to *Exploring the Unknown* on the Mutual Network every Sunday evening, 9 to 9:30 p.m., EDST.



RAYTHEON

Standardized

SUB-MINIATURE TUBES

FIRST DEVELOPED TO BE SHOT FROM GUNS—
NOW DESIGNED FOR RADIO RECEIVER USE

In October, 1940, Raytheon was the first tube manufacturer to take an NDRC contract to develop tubes for the Proximity Fuze project. In March, 1941, these tubes were successfully shot from guns and the Fuze project was established as being practical and effective. Late in 1941 Raytheon contributed a basically improved type of filament suspension which has since been employed in all vacuum tubes for the V T Fuze.

Since V T Fuzes could be used but once, the tubes were soldered in directly. This method is uneconomical for radio applications. With this in mind, Raytheon then developed a plug-in feature and low-loss socket which allows all the space-saving which characterizes these tubes. Today there are four basic types in the Raytheon line of sub-miniature tubes—all specifically designed for low-voltage radio receiver applications. Standard sockets are available permitting easy tube replacement and low cost chassis assembly operations.

These tubes have been standardized and registered with RMA. The day of pocket superheterodyne receivers for police patrol, fire-fighting, railroad operation and sport and entertainment reception is here, *now*. For long life, rugged construction, low assembly and maintenance costs—with user acceptance assured—use Raytheon Standard Sub-Miniature tubes. Technical data sheets available on request.

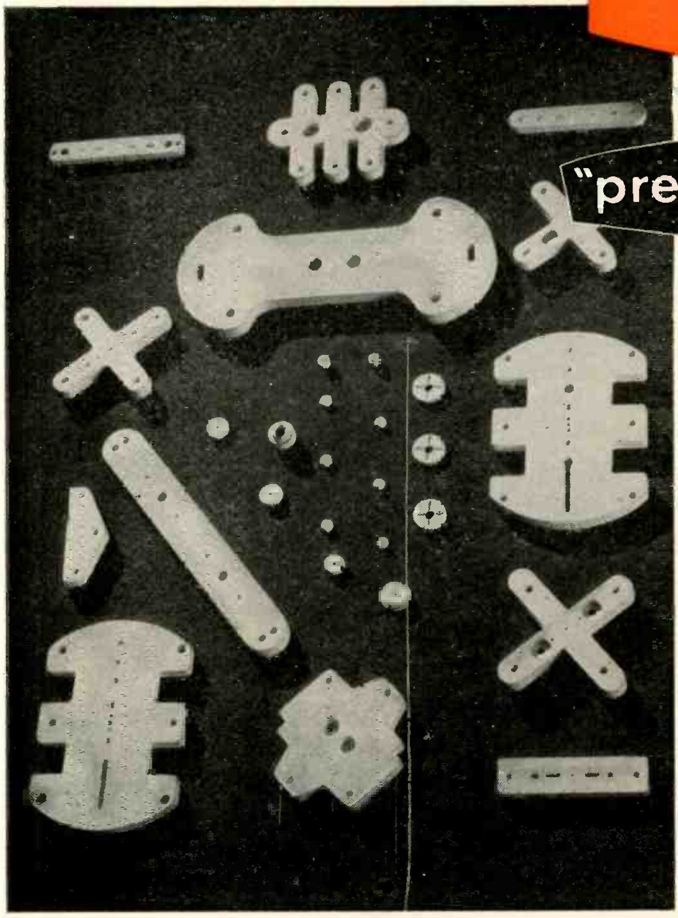
Tubes shown
actual size

RAYTHEON
MANUFACTURING COMPANY

Excellence in Electronics

RADIO RECEIVING TUBE DIVISION
Newton, Mass. • New York • Chicago

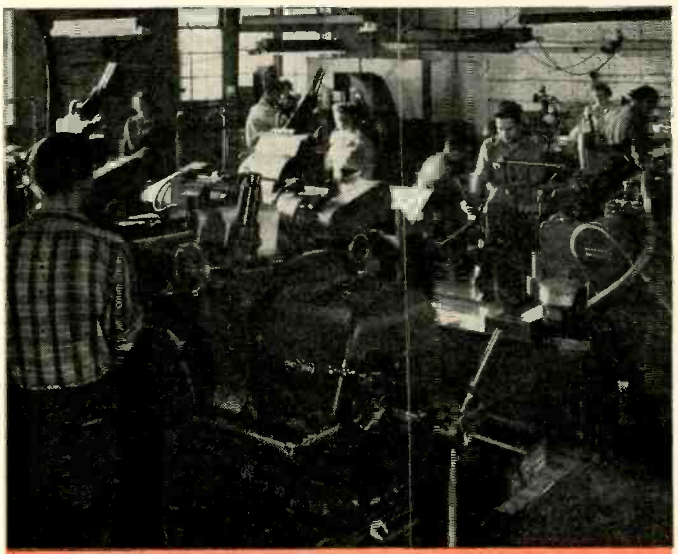
STUPAKOFF ceramic products



"precision made" means fewer headaches for you

Ceramic parts that are dimensionally accurate and mechanically strong are "headache eliminators" for your production men. Stupakoff takes special precautions throughout all steps of design and manufacture to see that every item is as nearly perfect as modern precision mass-manufacturing methods can make it. As a result, your production of assemblies is speeded, and you have less waste of labor and materials.

The dependable high quality of Stupakoff ceramics assures complete satisfaction.



Precision grinding of fired ceramic parts assures uniformity.

Electrolimit gauging checks dimensions to the fifth decimal.

STUPAKOFF

CERAMIC AND MANUFACTURING COMPANY · LATROBE, PA.

Export Department, 13 E. 40th St., New York, N. Y. Cable Address ARLAB, all codes.

LABORATORY INSTRUMENTS FOR SPEED AND ACCURACY

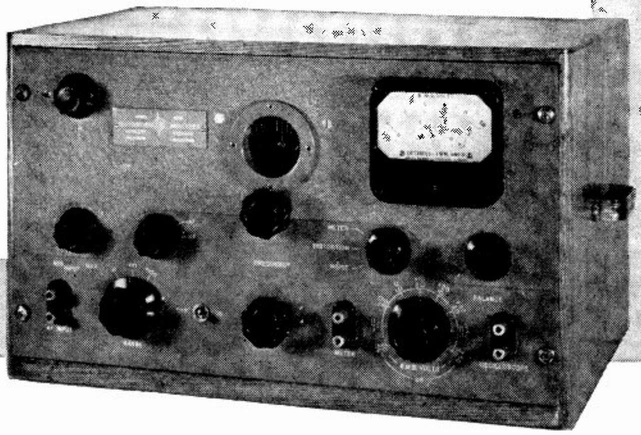
NEW -*hp*- DISTORTION ANALYZER

continously variable over entire AF spectrum

OUTSTANDING NEW FEATURES

Covers Audio Spectrum
Measures Noise as Small as 100 Microvolts
Linear r-f Detector
Ball-bearing Frequency Control Dial
High Order of Accuracy and Stability

MODEL 330B



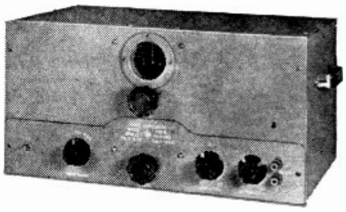
In the Model 330B Distortion Analyzer, the now-famous Hewlett-Packard resistance-tuned circuit is used in conjunction with an amplifier to provide many new and outstanding advantages. Here is an instrument which will measure "total" distortion at *any* frequency from 20 cps to 20,000 cps. Thus for the first time an instrument which covers the audio spectrum is available for distortion measurements. The Model 330B will also make noise measurements of voltages as small as 100 microvolts. A linear r-f dectector makes it possible to measure these characteristics directly from a modulated r-f carrier. This feature, coupled with the convenience, high sensitivity, accuracy, stability, and light weight which are traditional in all -*hp*- instruments, make the Model 330B uniquely valuable for broadcast, laboratory, and production measurement.

USES

The flexibility of the Model 330B leads to a wide number of applications. It may be used to measure the total distortion at any frequency of an audio signal, or of an audio-modulated r-f carrier. It may also be used as a voltmeter for measuring voltage level, power output, amplifier gain, or for any other use for which a high-impedance, wide frequency range, high sensitivity voltmeter is desirable. The frequency selective amplifier can be used as an audio-frequency meter to determine the frequency of an unknown audio signal. The Model 330B may also be used as a high-gain, wideband, stabilized amplifier, having a maximum gain of 75 db.

This new Model 330B Distortion Analyzer is particularly adapted for use as an all-round measurement device in the broadcast studio and broadcast transmitting room. Speed and ease of operation commend it for laboratory and production testing. Write today for complete data, prices and delivery information on -*hp's*- newest and finest distortion measuring instrument, the 330B Distortion Analyzer.

1156



NEW MODEL 201B RESISTANCE-TUNED AF OSCILLATOR

In FM and other fields where high fidelity is important, this new -*hp*- Model 201B Audio Frequency Oscillator will meet every requirement for speed, ease of operation, accuracy, and purity of waveform. Outstanding new features include: 3 watts output, distortion less than ½ of 1%, low hum level, new dial with ball-bearing drive, accurate expanded frequency calibration, improved control of output level. Because of its low distortion it is a distinguished companion instrument for the new Model 330B Distortion Analyzer. Write today for complete specifications on this new -*hp*- Resistance-tuned Audio Oscillator.

HEWLETT-PACKARD COMPANY

BOX 1156D • STATION A • PALO ALTO, CALIFORNIA

Audio Frequency Oscillators
Noise and Distortion Analyzers
Square Wave Generators
Signal Generators
Wave Analyzers
Frequency Standards
Attenuators
Vacuum Tube Voltmeters
Frequency Meters
Electronic Tachometers

It's Collins!
It's new!
It's ready!

. . . the Collins 30K—a NEW transmitter for amateur radio—thoroughly engineered for the continuous exacting requirements of "ham" operation. Check this partial list of features against your desires:

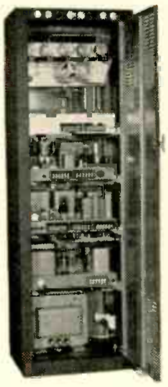
5 band operation · 500 watts input on CW · 375 watts input on Phone · Push-to-talk · Clean, sharp keying · Speech clipper · Bandswitching · Fully metered · Break-in operation · Vfo controlled

The high efficiency of the 30K assures a strong signal. In addition, the speech clipper circuit assists in maintaining a high modulation level, with no danger of overmodulation. Speech clipping also improves intelligibility. Brass pounders will proudly note the clean keying at any speed.

The exciter unit, built into a receiver type cabinet, may be placed on the operating desk. A highly accurate and stable variable frequency oscillator, the product of years of research and manufacturing experience, is calibrated directly in frequency. The frequency can be varied considerably without retuning the final.

The attractive appearance of this up-to-the-minute transmitter will improve any "shack." Its smooth, easy operation will please you.

Write today for complete details. Collins Radio Company, Cedar Rapids, Iowa; 11 West 42nd Street, New York 18, N. Y.



The Collins 30K

FOR RESULTS IN AMATEUR RADIO, GET... COLLINS

more efficient ... in miniature

ACTUAL SIZE

Flickering firebrands of burning fagots, smoking pine knots and pitch soaked moss lacked the convenience and effectiveness of the modern flash light. It took the same type of imagination, backed by science, to develop efficient miniature mobile lighting as it did to develop miniature Electron Tubes.

Due to their inherent improved characteristics, TUNG-SOL Miniatures are found in high frequency circuits in which the use of the larger type tubes would be impractical. In other circuits TUNG-SOL Miniatures are also more satisfactory. They are more rugged and more resistant to vibration. Because they are smaller, and lighter, TUNG-SOL Miniatures make possible the production of smaller and lighter equipment. This is the trend of today.

TUNG-SOL Engineers will be glad to help you interpret your tube requirements in terms of Miniatures. TUNG-SOL is a tube manufacturer, not a set builder. The disclosures of your plans you make in consultation will be held in strictest confidence.

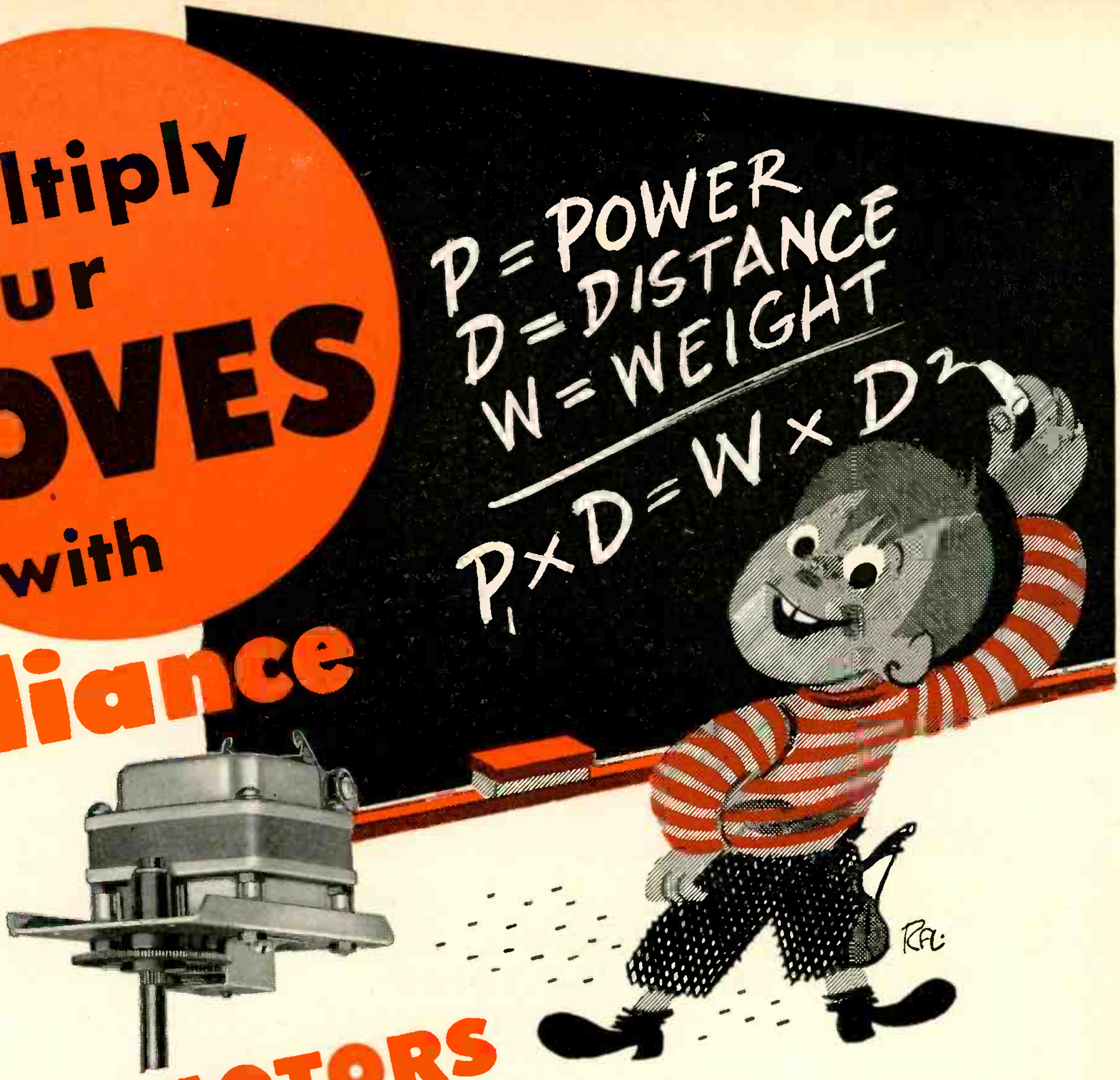
TUNG-SOL

vibration-tested

ELECTRONIC 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

multiply your MOVES with alliance



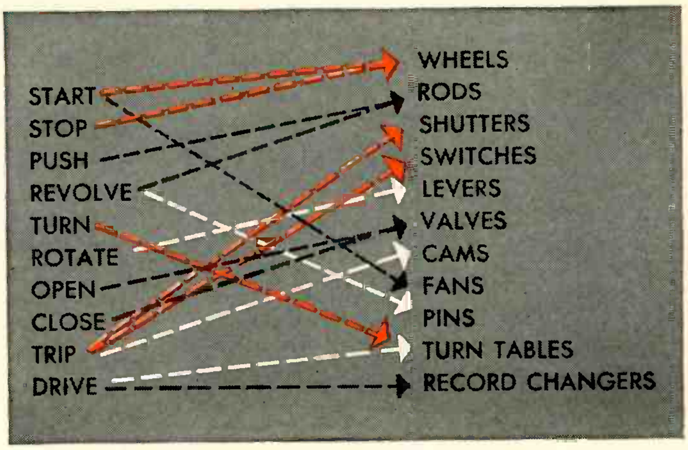
Model RR enclosed split-phase Reversible Motor. Alliance Motors are rated from less than 1-400th up to 1-20th H.P. With or without integral gears.

POWR-PAKT MOTORS

To get more motion—remote control—automatic action—that's the aim of most modern designs!

Alliance miniature Powr-Pakt Motors—light weight, compact, easy to install, grew from the millions of Alliance Phonomotors made for the radio industry.

As vital component power links in every electronic, radio and heating control sequence, they'll reduce waste motion, manual effort, and *Multiply Your Moves!*



WHEN YOU DESIGN—KEEP alliance MOTORS IN MIND

ALLIANCE MANUFACTURING COMPANY • ALLIANCE, OHIO

ALLIANCE TOOL AND MOTOR LTD., TORONTO 14, CANADA

STACKPOLE

MOLDED IRON CORES

STANDARD AND HIGH-FREQUENCY TYPES

A pioneer in Iron Core production, Stackpole can supply practically any desired type from 100 cycles to upward of 175 megacycles and in an infinite variety of shapes, sizes and characteristics. Also available are High-Resistivity Cores showing a resistance of practical infinity; Insulated Cores wherein the screws are kept out of the coil field and "Q" consequently increased; Iron Cores for choke coils; and Side-Molded Iron Cores featuring uniform permeability with respect to linearity. Write for details and samples of any type.

for higher "Q" STACKPOLE SCREW-TYPE MOLDED CORES

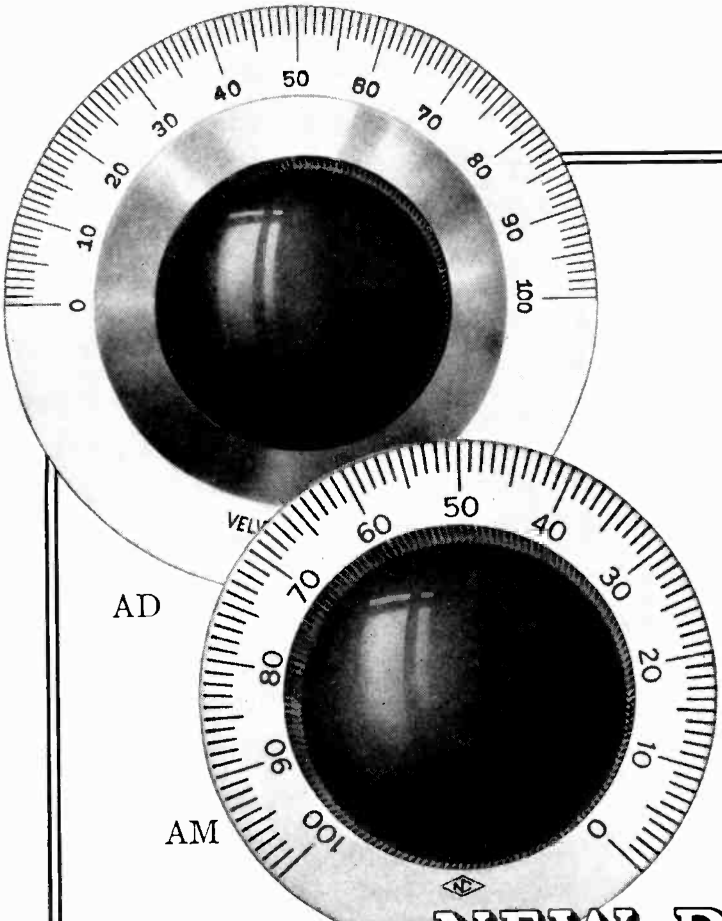
These Stackpole developments are proving highly popular for circuits where small assemblies are the order of the day, and where "Q" must be kept at an absolute minimum. The cores themselves are threaded, thus eliminating the conventional brass core screw. Tubes can be threaded to fit cores if desired. More economical, however, is the use of a wire C-spring clip placed (obtainable from usual sources of supply) in a slot in an unthreaded tube. Stackpole Screw-Type Cores are ideal for the design of I-F and dual I-F Transformers for AM and FM.

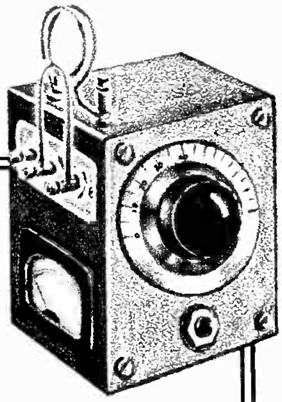
IRON SLEEVE TYPES
. . . *for better coils in less space*

By use of Stackpole Sleeve Cores, much smaller cans *of any material* may be used to provide "Q" that is equal to, or better than, that of conventional cores and cans. Thus they facilitate an exceptionally high order of tuning unit efficiency in greatly reduced size. Cans are not always necessary — and, where they are, inexpensive aluminum containers may often be used.

LOOK FOR THE STACKPOLE MINUTE MAN . . . your assurance of the highest in molded materials quality.

STACKPOLE CARBON CO., *Electronic Components Division,* ST. MARYS, PA.





NEW DIALS

Wartime requirements for accurate smooth-working dials resulted in the design of these two new models. Both make use of the time-tested "Velvet Vernier" drive unit which for more than twenty years has been a favorite because of its incomparably smooth action and sensitive control. The Type AM Dial is three inches in diameter and is available with 2, 3, 4, 5 or 6 scale. The four-inch Type AD Dial is made with 2, 3, 4 or 5 scale. Both are handsome in appearance and moderate in cost.

DIAL SCALES

Scale	Divisions	Rotation	Direction of Condenser Rotation for increase of dial reading
2	0-100	180°	Counter Clockwise
3	100-0	180°	Clockwise
4	150-0	270°	Clockwise
5	200-0	360°	Clockwise
6	0-150	270°	Counter Clockwise

NATIONAL COMPANY, INC., MALDEN, MASS. U.S.A.

KNIT MONEL MESH

Shielding Rings

for h-f electronic applications

HERE'S a war development that may offer an answer to your shielding problems in high-frequency equipment.

It is shielding rings of resilient Monel mesh. They were first used by the U. S. Army Signal Corps.

The resiliency of Monel mesh assures continuous contact at all points. And, Monel's corrosion resistance minimizes any loss of over-all conductivity from attack by moisture-laden air or sea water.

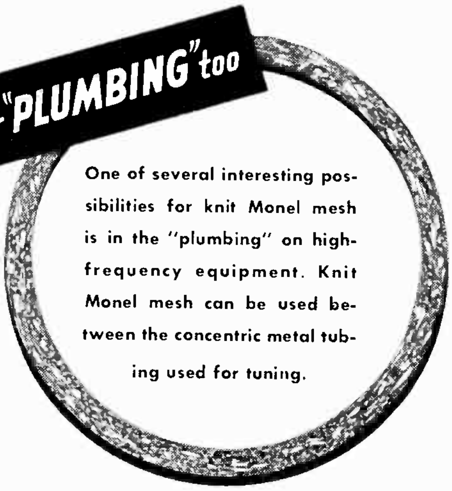
When used in place of fabricated sheet metal shields, these rings speed production and assembly . . . reduce space requirements . . . simplify disassembly.

And, where fluid seal attachments are needed, designers find that Monel can be satisfactorily bonded to rubber-like materials.

Most important, Monel mesh shielding rings do a fine job of "frustrating" straying h-f currents. Currents that "want out" have to run around in circles until they crawl back into the box.

Investigate this new shielding method. Knit Monel mesh can be made into rings of all types and sizes to fit individual requirements. For more information write: Metal Textile Corporation, Orange, New Jersey.

for "PLUMBING" too

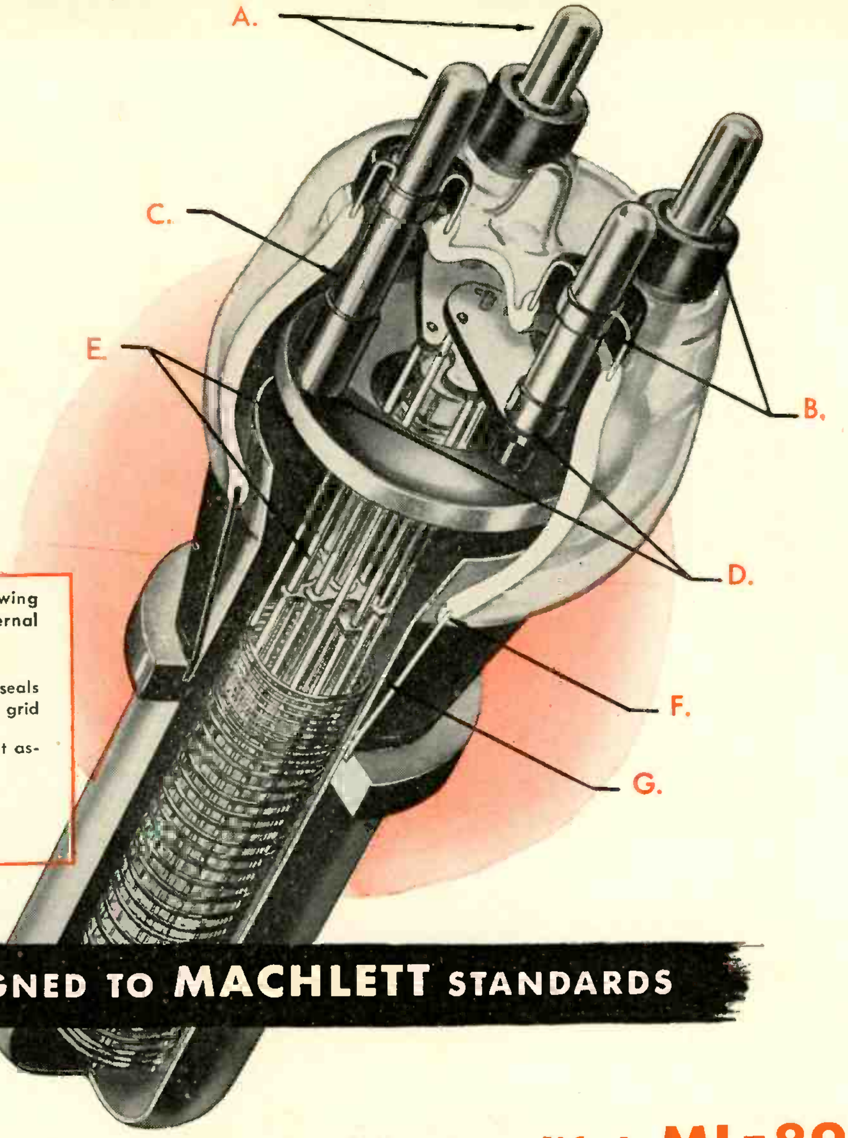


One of several interesting possibilities for knit Monel mesh is in the "plumbing" on high-frequency equipment. Knit Monel mesh can be used between the concentric metal tubing used for tuning.

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street, New York 5, N. Y.

get to know all the— **NICKEL** INCO TRADE MARK **ALLOYS**

MONEL* • "K" MONEL* • "R" MONEL* • "KR" MONEL* • "S" MONEL*
INCONEL* • NICKEL • "L" NICKEL* • "Z" NICKEL* *Reg. U. S. Pat. Off.



Sectional view of the ML-889-A, showing features typical of Machlett external anode tube construction.

- A. Gold-plated contact surfaces
- B. Rugged Kovar grid and filament seals
- C. One-piece high-conductivity copper grid and filament support leads
- D. Rigidly-supported grid and filament assemblies
- E. Surgically-clean internal parts
- F. Rugged Kovar plate seal
- G. One-piece anode and shield

REDESIGNED TO MACHLETT STANDARDS

For better performance and longer life! ML-892

HERE is another outstanding example of Machlett's ability to apply to the design and manufacture of high-power triodes its unique skills acquired in the manufacture of X-ray tubes. Remember, those skills were developed through almost 50 years of X-ray tube production—and an X-ray tube presents manufacturing problems of the greatest severity in the electron-tube art. Machlett's ability to solve those problems has resulted in making it the largest producer of X-ray tubes in the world. Note these features of the ML-892:

1. Heavy Kovar sections for grid and plate seals, instead of feather-edge copper. Result—greatly increased mechanical strength.

2. Grid assembly supported by heavy Kovar cup, for strength and stable inter-element spacing.

3. Filament assembly greatly strengthened to increase life and preserve correct spacing.

4. All internal parts processed by special Machlett techniques which prevent contamination by foreign particles, assuring permanent outgassing.

5. Tube pumped by unique Machlett continuous, straight-line, high-voltage process, assuring same high standards maintained in Machlett high-voltage X-ray tubes.

• • •

For complete details of this greatly improved tube, write Machlett Laboratories, Inc., Springdale, Connecticut.

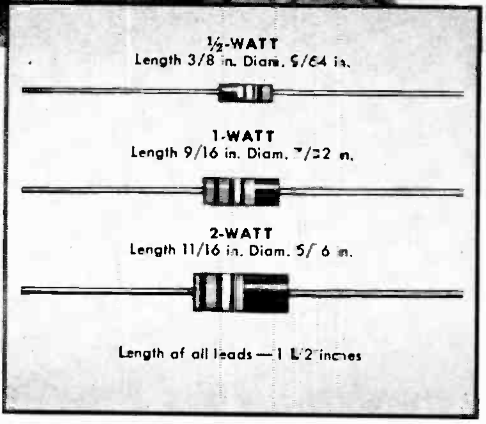
GENERAL CHARACTERISTICS

	ML-892	ML-892-R
Filement Voltage	22	22 volts
Filament Current	60	60 amps.
Amplification Factor	50	50
Maximum frequency for full power	1.6	1.6 mc.
Capacity grid to plate	27	30 uuf
Capacity grid to filament	18	18 uuf
Capacity plate to filament	2	2 uuf
Cooling	Water 3 to 8 G.P.M.	Air 400-700 C.F.M.

MACHLETT

APPLIES TO RADIO AND INDUSTRIAL USES

ITS 49 YEARS OF ELECTRON TUBE EXPERIENCE



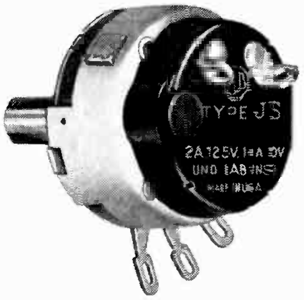
"These fixed resistors pack the greatest wattage capacity for their size"

Bradleyunit solid-molded, fixed resistors are not rated on the basis of the conventional 40 C ambient temperature . . . instead they are rated at 70 C ambient temperature.

Bradleyunits . . . in ½-watt, 1-watt, and 2-watt ratings . . . will operate at full rating for 1000 hours in an ambient temperature of 70 C, with a resistance change of less than 5 per cent. They pass salt water immersion tests without wax impregnation. All three sizes are available in standard R.M.A. values from 10 ohms to 22.0 megohms, inclusive.

Such *"extra"* performance improves the dependability of your electronic equipment. Specify Bradleyunit resistors . . . and you add *"extra"* quality to your products.

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



Type J Bradleyometers are the only continuously adjustable, solid-molded resistors having a 2-watt rating with a generous safety factor. Any resistance-rotation curve is available.

A·B
Quality

ALLEN-BRADLEY

FIXED & ADJUSTABLE RADIO RESISTORS

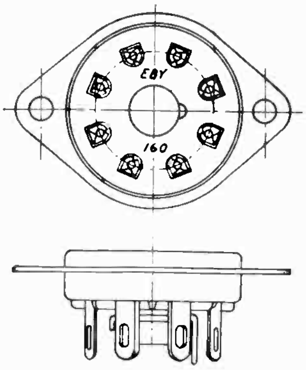
QUALITY

NEW EBY SOCKETS

Lock-In, Octal, and Non-Microphonic

LOCK-IN

(Glass Bonded Mica)



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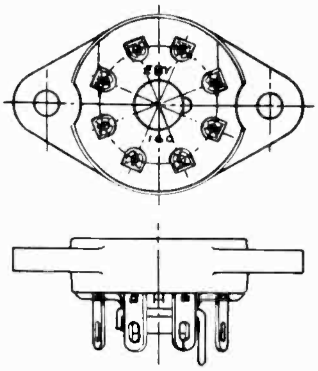

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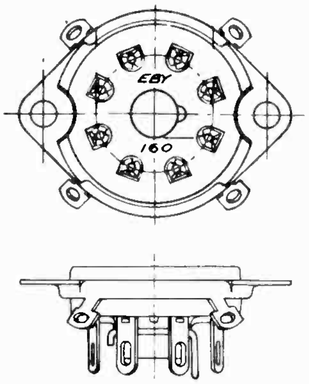
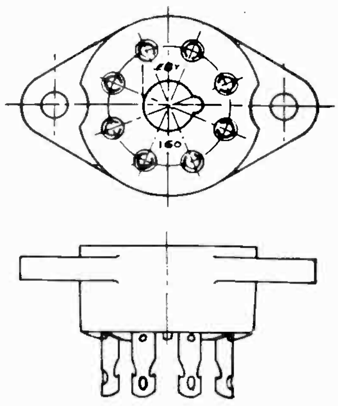


Chassis Hole—1 1/16" dia.
Mounting Centers—1 5/16"
Mounting—Top or Bottom
With or without Grounding Lugs

OCTAL



Chassis Hole—1 1/16" dia.
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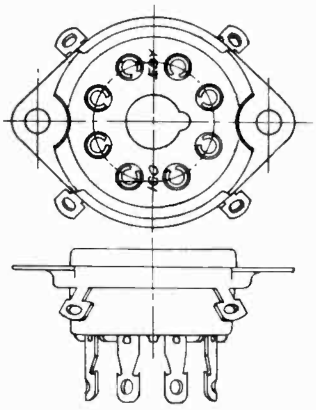

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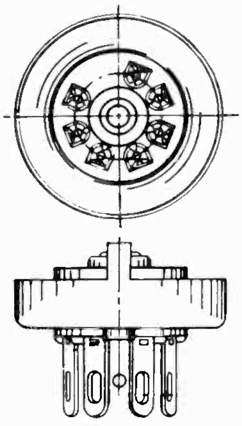

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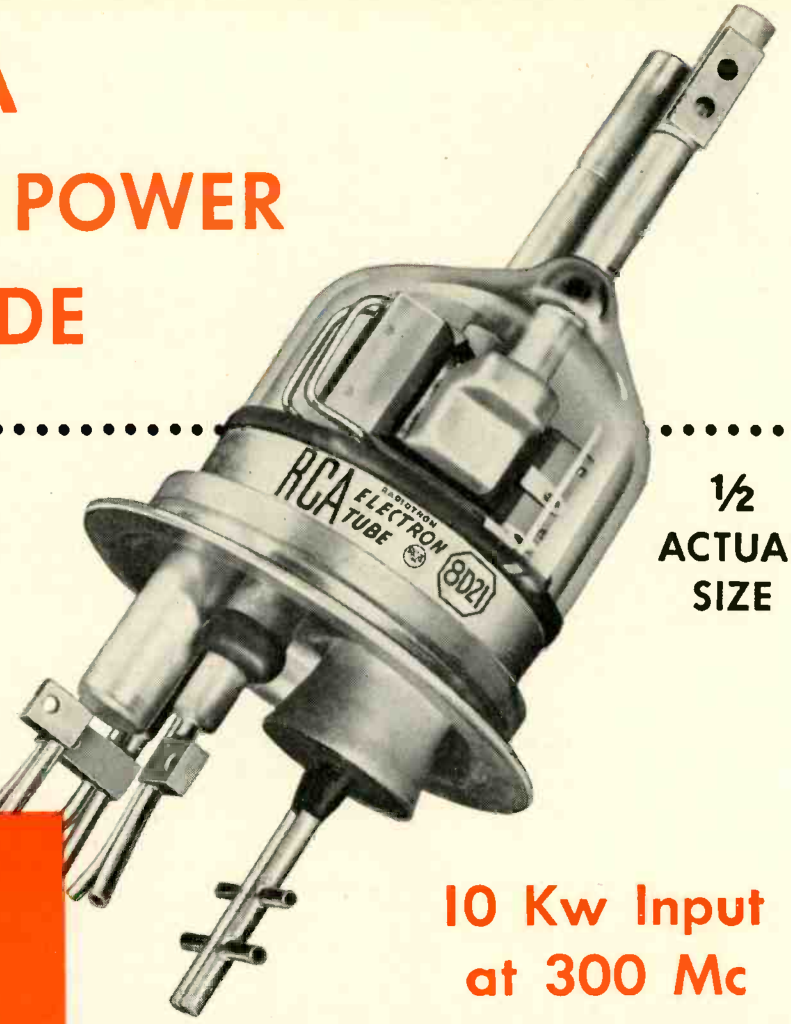
8D21 TWIN POWER TETRODE

An important contribution to Television Broadcasting



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10 Kw Input at 300 Mc

Unusual construction is indicated by this view of the header with filament, grid #1 and grid #2 in position. Precision cast and machined electrodes are connected to water ducts for internal cooling.

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Because of electron optical principles incorporated in its design, the 8D21 has high power sensitivity and thus its driving-power requirements are low.

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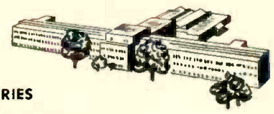
A technical bulletin on the RCA-8D21 is available on request. RCA Tube Application Engineers will be glad to work with you in adapting this or any other RCA tube type to your equipment designs. Address RCA, Commercial Engineering Department, Section D-18F, Harrison, N. J.



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AND

WAVES AND ELECTRONS

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INSTITUTE NEWS AND RADIO NOTES

WAVES AND ELECTRONS

SECTION

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The amazing wealth of accomplishments of science and technology during the recent decades, and the corresponding major opportunities for determined and effective thinkers in these fields are subjects of particular interest to radio-and-electronic engineers. There is accordingly presented to the membership the following guest editorial written by an eminent electronic engineer and pioneer, who is active in the research laboratory of the General Electric Company and is a Fellow of the Institute, a member of its Board of Directors, and a member of its Executive Committee.—*The Editor.*

There Is Always Room at the Top

W. C. WHITE

When in the late eighteen eighties Thomas Edison put into service the first large public-utility power station, the power supply was direct current, which of course is zero frequency. Although at the time it was a wonderful advance in engineering, it had severe limitations in regard to the area that could be served and its flexibility.

The advent of the alternating-current system, even at the low frequency of 25 cycles, gave rise to a great expansion of the central-station industry and the increase of frequency to 60 cycles brought on still further improvements. Meanwhile, other engineers in a different field were expanding knowledge on devices and circuits for frequencies in the range of hundreds to several thousands of cycles per second, and this was laying the foundation for our present universal telephone system.

Then, of course, came the early wireless engineers struggling to establish transatlantic and other long-distance contacts on a commercial basis at tens to hundreds of thousands of cycles per second.

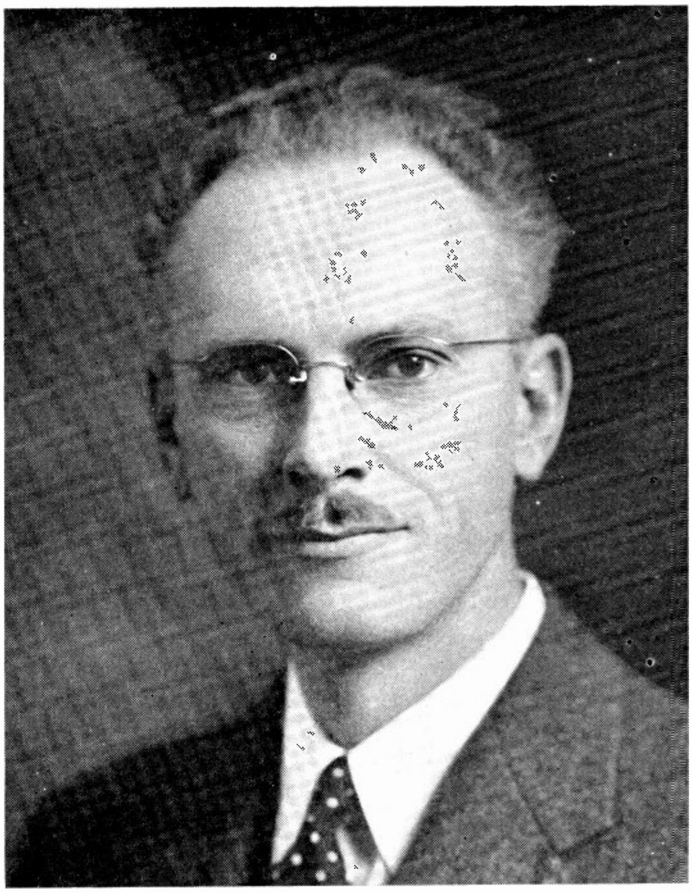
Following World War I, radio engineers provided the basis on which was established our present broadcast system at around a million-cycle frequency. Frequency-modulation broadcasting, the latest improvement in that field, is expected to expand greatly the number of both transmitters and receivers, and this is based on the use of still higher frequencies.

The point to notice is that every time a new and distinctly higher-frequency band has been opened up to use by new engineering knowledge a whole new industry has come into being, involving new capital investment, new public services, and employment to many additional thousands or even hundreds of thousands of persons.

Television is here with its utilization of frequencies of the order of a hundred-million cycles or even higher, and it constitutes one of the country's most promising postwar industries. Already new and improved tubes and techniques are being employed experimentally for frequencies severalfold higher than in use in present-day television. These developments are leading to the long-distance radio relaying of programs and the utilization of color.

Now today, as a result of developments during World War II, physicists and radio engineers have carried the advance still further and learned how to generate and handle frequencies of the order of billions of cycles.

In view of the past record, where each upward step in frequency has expanded greatly the field for some branch of electrical engineering, do we not have every reason to expect that this new knowledge will soon create its share of new business opportunities, employment, and benefits to our normal daily lives? Possibly there may be involved a whole new industry not now visualized.



Frank H. R. Pounsett

Chairman, Toronto Section, 1946

Frank H. R. Pounsett was born in London, England, September 12, 1904, and moved to Canada in 1910. He was active in amateur radio following World War I and a member of the Wireless Association of Ontario.

He received the B.A.Sc. degree in electrical engineering, communications, at the University of Toronto in 1928. From 1928 to 1934, he was a member of the radio engineering staff at the De Forest Radio Corporation in Toronto, and was responsible for design and development of complete broadcast receivers and associated equipment. In 1934, he became chief engineer of the radio division of the Stewart-Warner—Alemite Corporation, Belleville, Ontario, where he remained until 1940. In that year, Research Enterprises Limited, a Crown Company, was formed at Toronto to manufacture optical glass, optical instruments, and radar equipment for the United Nations Armed Forces. All radar equipment manufactured in Canada was assembled and shipped from this large plant. As chief engineer of the radio division, Mr. Pounsett was responsible for the production-development and engineering of numerous types of radar equipment and accessories. On January 1, 1946, Mr. Pounsett was appointed chief engineer of the Stromberg-Carlson Company, Limited, at Toronto, where he is responsible for the design and engineering of broadcast receivers, amplifiers, sound systems, telephone, and other communications equipment, for Stromberg-Carlson in Canada.

Mr. Pounsett joined the Institute of Radio Engineers as an Associate in 1926 and was transferred to Senior Member grade in 1944. He is at present chairman of Toronto Section, and a member of the executive committee of the Canadian Council of the I.R.E. He is also a member of the Association of Professional Engineers of Ontario and of the Royal Canadian Institute. He has served on many committees of the Engineering Division of the RMA in Canada, and of the Canadian Electrical Code.

A New Angular-Velocity-Modulation System Employing Pulse Techniques*

JAMES F. GORDON†, ASSOCIATE, I.R.E.

Summary—**A method is described wherein crystal-controlled phase- or frequency-modulated carriers may be produced having relatively large deviation angles.**

A circuit is described wherein the harmonic distortion during modulation is held to a low value.

An experimental transmitter is shown utilizing one form of the system. Also shown are oscillograms of the voltages occurring in various portions of the modulation system.

INTRODUCTION

It HAS been generally recognized that crystal-controlled sources for angular velocity modulation are desirable because of the simplicity of frequency stabilization. It has been recognized further that crystal-controlled sources having large deviation characteristics are even more desirable since the number of multiplier stages between the crystal oscillator and the antenna stage may be reduced. Many systems, though capable of providing relatively large angular deviations during modulation, are useful only at the smaller deviation angles because of the excessive distortion encountered at the larger deviations.

The system here described provides a means of obtaining relatively large deviation angles which may be used to produce phase- or frequency-modulated radio-frequency carriers having low distortion.

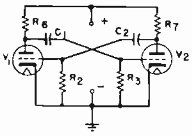


Fig. 1—The multivibrator circuit of Abraham and Bloch

Consider the well-known multivibrator circuit of Fig. 1. The ideal output of such a circuit where both halves are electrically symmetrical is a square wave with the conducting periods equally divided between the two tubes. In actual practice it is not possible to accomplish the ideal, and the anode-voltage conditions for either tube during the conducting period will more closely follow the conditions shown in Fig. 2.

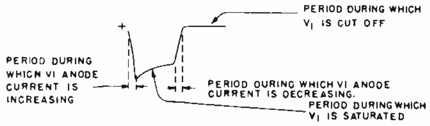


Fig. 2—The actual multivibrator output from either anode will more closely resemble this wave form during the conducting period, rather than the ideal square wave.

If the time constants of the circuit of Fig. 1 are changed to give V_2 a longer conducting period, the ideal voltage conditions for V_1 anode would appear as in Fig. 3. If the time constants were changed to give V_1 the longer conducting period, the V_1 anode conditions would appear as in Fig. 4.

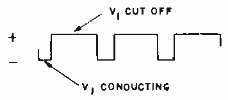


Fig. 3—The ideal voltage conditions for V_1 anode where V_2 has the longer conducting period.

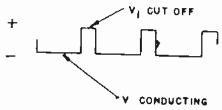


Fig. 4—The ideal voltage conditions for V_1 anode where V_1 has the longer conducting period.

From this it is evident that the conducting time may be made to favor either V_1 or V_2 by changing the time constants of the circuit.

If the time constants of the two circuits are left identical and the negative potential of one of the tube grids is increased, as in Fig. 5, with respect to the other grid, the grid with the highest negative potential will go negative sooner and stay negative longer than the other.

The result is that V_1 has a longer conducting period than V_2. If the V_2 negative grid voltage was to be reduced to a lower negative value than that of V_1, then V_2 would have the longer conducting period.

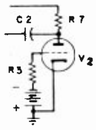


Fig. 5—The conducting time of either of the tubes in the two-tube multivibrator circuit may be influenced by changing the grid voltages.

From the foregoing it is evident that the time at which V_1 or V_2 changes from a conducting to a nonconducting condition or vice versa may be controlled by the amplitude of the grid voltage on either tube with respect to the grid voltage of the other.

APPLYING AN AUDIO VOLTAGE TO THE MULTIVIBRATOR

If a sine voltage is applied to either the V_1 or V_2 grid, the conducting time of the tubes would vary in accordance with this voltage. Examination of the V_1 anode conditions shows that the switch-over period varies from minimum to maximum as shown in Fig. 6,

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* Decimal classification: R146.2×R355.914.41. Original manuscript received by the Institute, January 17, 1946. Presented, 1946 Winter Technical Meeting, New York, N. Y., January 24, 1946.

† Bendix Radio Division, Baltimore, Maryland.

from the instant the V_1 anode goes positive. The minimum time, as controlled by the positive peak of the audio cycle, will be as small as the switch-over time, and the maximum time as controlled by the negative peak of the audio cycle will be within the length of the switch-over time of being the major portion of a cycle later.

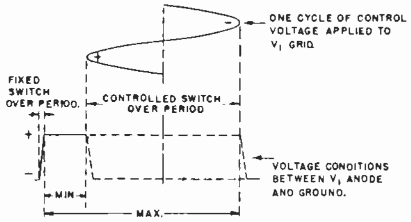

Fig. 6—The relationship between the positive and negative peaks of the audio modulating voltage and the minimum and maximum excursion of the switch-over period of the multivibrator.

It is theoretically possible to obtain nearly a zero- to 360-degree variation of the switch-over time in this manner, or a deviation of almost 180 degrees either side of the center position. In actual practice, this great a deviation is not completely accomplished. A phase deviation of the switch-over period which may be controlled by the amplitude of a modulating voltage is thus realized.

If the output voltage from V_1 anode is differentiated, a series of positive and negative pips or pulses of very short duration results, as in Fig. 7.

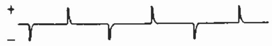

Fig. 7—Differentiated output of the ideal multivibrator where conducting periods are equal.

The positive pips will remain stationary during the application of a modulating voltage to the grid of V_2. (See Fig. 18(h).) The negative pips will change position.

By clipping the positive pulses and inverting and amplifying the negative pulses, a series of positive pulses which are suitable to drive a class C amplifier is obtained (see Fig. 18(f)). (This is a form of pulse-position modulation which forms the basis of a forthcoming paper).

The relationship between the position of the negative pips from the differentiated V_1 anode voltage and the modulating voltage is shown in Fig. 8.

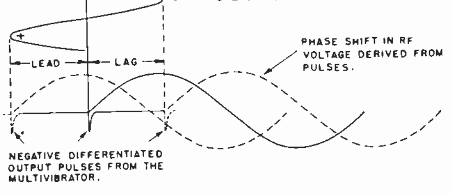

Fig. 8—The relationship between the multivibrator modulating voltage, the differentiated multivibrator output pips, and the resultant radio-frequency voltage.

By tuning the plate circuit of the class-C amplifier to a frequency which is comparable to the repetition rate of the grid pulses driving it, a radio-frequency voltage is obtained which may be controlled in phase by the phase variations of the switch-over time in the multivibrator circuit.

There are several factors which enter into the actual application of this circuit to radio communications, as follows:

(1) The multivibrator is not a sufficiently stable oscillator in itself to provide adequate frequency control for transmitting equipment. The multivibrator becomes even more unstable if the previously described modulation is used.

(2) The multivibrator must be capable of operating at frequencies of at least 100 kilocycles and higher with good square wave form.

(3) Accurate synchronizing of the multivibrator from a crystal-controlled source requires that the crystal-oscillator output be preferably in the form of a sharp pulse. For the circuit described here this pulse should be negative in polarity.

(4) Circuit reactances should be such as not to make the multivibrator phase deviation nonlinear with respect to the amplitude or frequency of the modulating voltage.

CONTROLLING THE MULTIVIBRATOR FREQUENCY

A crystal oscillator may be used as the multivibrator control by applying its output to an amplifier (Fig. 9)

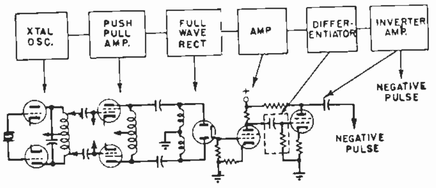

Fig. 9—Block diagram and schematic of crystal-oscillator and rectifier circuit for controlling the multivibrator.

which feeds a full-wave rectifier. The rectifier output will consist of positive pulses at twice the oscillator frequency (see Fig. 10).

Fig. 10—Typical full-wave rectifier output.

These may be amplified and differentiated and the negative pulses eventually derived may be used to synchronize the multivibrator.

Another method is to synchronize a blocking oscillator with a crystal and use the blocking oscillator output to synchronize the multivibrator.

The first method requires more tubes and power, while the second requires fewer tubes, is simpler, and has lower power requirements (see Figs. 9 and 11).

In the first case, any asymmetry in the rectifier output is likely to cause unwanted phase variations which will present themselves as noise or undesired sidebands of the final transmitter output frequency. Careful balancing of the rectifier plate transformer will tend to reduce this type of trouble.

In the second method, there are two possibilities for noise and attendant instability at the final output frequency. The first is that the blocking oscillator may not trigger off at exactly the same time for each pulse, and the second is that the multivibrator might react on the blocking oscillator during modulation to create instability.

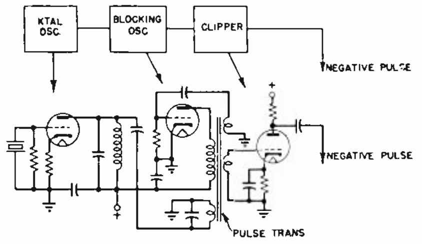

Fig. 11—Block diagram of synchronized blocking oscillator for driving the multivibrator.

A simple way to synchronize the blocking oscillator is to feed the synchronizing voltage into an extra winding of the pulse transformer. In almost every case the blocking oscillator will trigger off on the steepest portion of the synchronizing wave (see Fig. 18(a)). By using a strong blocking-oscillator pulse and coupling it loosely to the multivibrator, there is no reaction on the blocking oscillator due to multivibrator modulation.

OPERATING THE MULTIVIBRATOR AT RADIO FREQUENCIES

High-mu triodes such as the 7A4, XXL, or 6J5 will operate satisfactorily as multivibrators between 100 and 200 kilocycles with fair wave form. A type 7F8 will operate satisfactorily to at least 400 kilocycles.

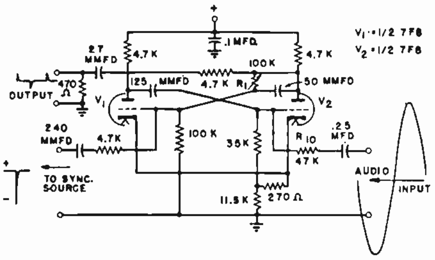

Fig. 12—A high-frequency two-tube multivibrator circuit which will operate between 200 and 400 kilocycles, and which may be modulated to produce negative phase-modulated pulses.

The circuit of Fig. 12 is a modified form of the simple two-tube multivibrator described in the introduction. Here the synchronizing voltage is fed to the grid of V_1, and the audio modulating voltage to the grid of V_2. The output is taken from the V_1 plate.

It is necessary to keep the plate load resistances low enough to provide fairly good square wave form at the multivibrator frequency and at the same time have sufficient multivibrator output. A voltage of 5 volts or more peak from the multivibrator is sufficient for satisfactory operation.

Close assembly of the components around the tube sockets is desirable to minimize stray coupling.

The multivibrator is easily disturbed by stray fields, and for this reason the circuit should be well shielded.

AUDIO-FREQUENCY LOSSES IN THE MULTIVIBRATOR

There are no appreciable audio-frequency losses in the multivibrator. Note that the relatively high resistance to ground from the grid of V_2 will not unduly load a 500-ohm input to it through the decoupling resistor R_{10} (see Fig. 12). In a like manner, the input circuit is prevented from reacting on the multivibrator. The degeneration accomplished across the V_2 cathode resistor is desirable. By using a suitable radio-frequency choke in place of R_{10}, audio losses may be further minimized. The root-mean-square sine-wave input at the audio input terminals of Fig. 12, to accomplish a phase swing of 90 degrees, is approximately 15 volts.

THE CYCLE OF OPERATION

A negative pulse of 5 to 10 volts amplitude and about a fifth of a microsecond duration (Fig. 18(b)) drives V_1 grid negative (Fig. 18(c)) causing V_1 anode to go positive, which drives V_2 grid positive firing V_2, which maintains V_1 grid negative for a period depending upon the circuit time constants and the grid biases. The V_1 grid bias eventually leaks off and V_1 grid goes positive, firing V_1. The action is now reversed and V_1 remains conducting, due to its positive grid, until another pulse arrives to trigger V_1 grid negative.

Fig. 13—A sharp negative synchronizing pulse initiates each new multivibrator cycle.

The circuit is adjusted by proper choice of common cathode resistance such that the multivibrator will just oscillate of its own accord. The time constants are so chosen that the rate of self-oscillation is somewhat lower than the required rate during synchronized operation. By so adjusting the circuit, the initiating negative pulse to the V_1 grid always controls the beginning of a new multivibrator cycle (see Fig. 13 and Fig. 18(c)).

The circuit may be adjusted as a "flip-flop" circuit entirely, but the method of just biasing the circuit to sustain self-oscillation requires a less-powerful synchronizing pulse. If the multivibrator constants are too low, the circuit may divide frequency; or, on the other hand, if they are too high, multiplication may result. Both conditions are undesirable for proper operation of the circuit.

Since the method of coupling the negative initiating pulse to the V_1 grid will affect the time constants of the circuit, the multivibrator must be set up and tested with this part of the synchronizing circuit attached. A series resistance in this part of the circuit is helpful in reducing capacitive reactance between the blocking oscillator and the multivibrator.

By making R_1 variable, the switch-over time may be adjusted to occur in the center of the multivibrator cycle. This should always be the resting point of the

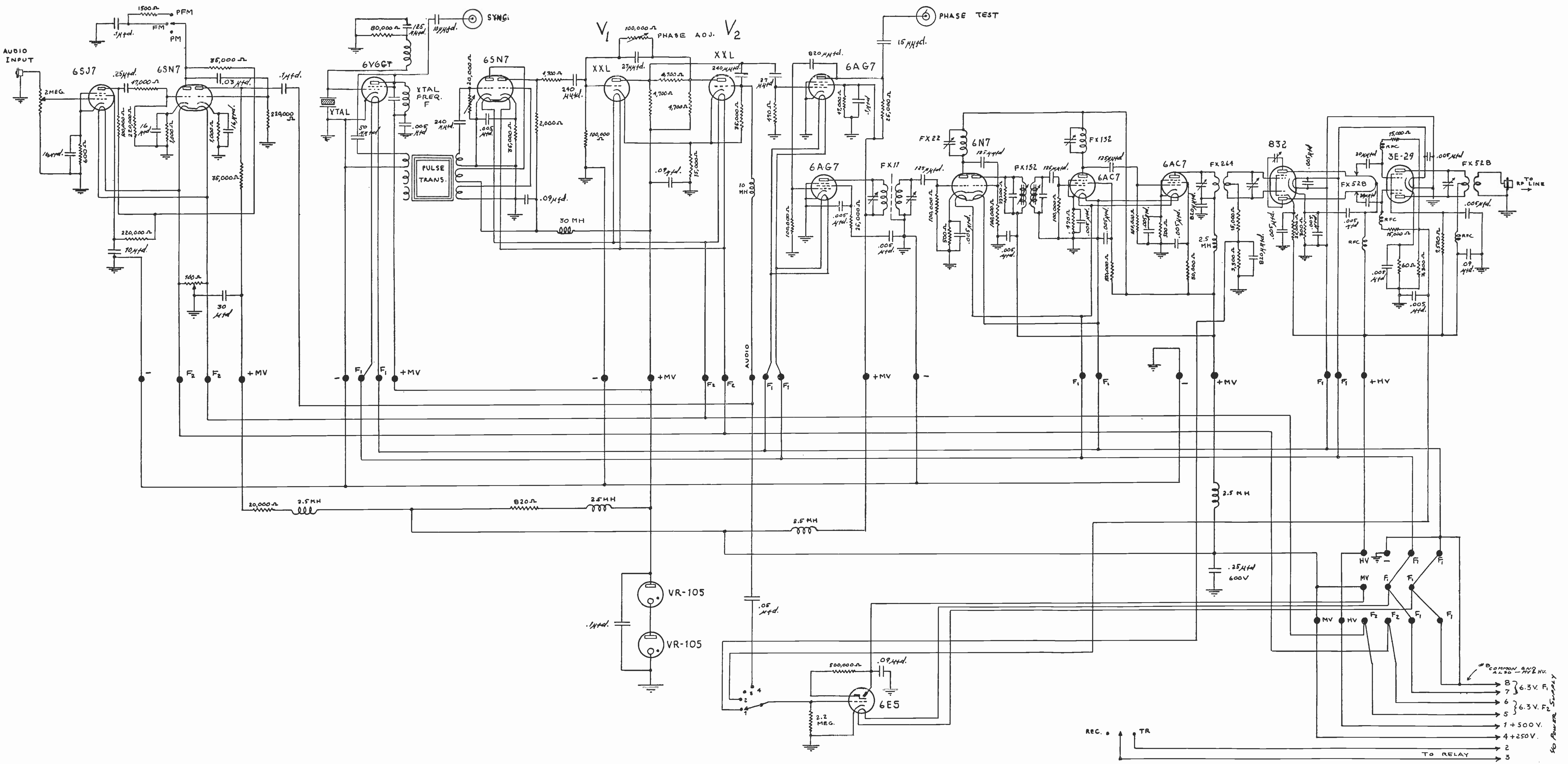

Fig. 15—Experimental very-high-frequency transmitter for angular-velocity modulation.

multivibrator switch-over period in the absence of modulation. The values of the circuit in Fig. 12 have been arrived at experimentally and will vary somewhat with the arrangement of components and wiring, circuit loading, etc.

Since, during a modulation cycle, if anode saturation or grid cutoff of V_2 took place during the multivibrator switch-over period (i.e., during the time V_2 grid was going from negative to positive), this switch-over time would be altered. For a part of the time during a modulation cycle V_2 is cut off, and the remainder of the time it is conducting near saturation. If grid current during the part of the multivibrator cycle in which V_2 is conducting is high, then large grid current will flow in the V_2 grid resistor, creating audio distortion which will be largely second harmonic since it is effectively occurring during only the positive half of the modulating cycle. To reduce distortion from this source, the V_2 grid may be returned to a tap on the cathode resistor as shown in Fig. 12.

Distortion from this source does not have as great an effect as might at first be supposed. The period during which this distortion will be effective is the time during which V_2 goes from saturation to cutoff. The relationship between a positive pulse which is originally derived from the output of V_1 anode and the period during which V_2 goes from saturation to cutoff is shown in Fig. 14.

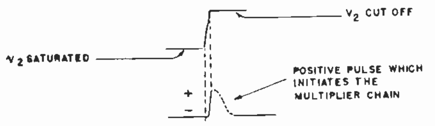

Fig. 14—The relationship between a positive pulse derived from the first multivibrator-tube anode and the period during which the second tube goes from saturation to cutoff.

The positive-pulse peaks are effective in driving the multiplier chain and these peaks occur near the cutoff point of V_2, which is the point where distortion of the type just mentioned will be negligible. In the experimental transmitter of Fig. 15 it was not found necessary to use the cathode resistance in order to obtain good intelligence.

THE EXPERIMENTAL TRANSMITTER

An experimental transmitter was set up to test the system under actual application. Two XXL-type tubes were used experimentally and performed satisfactorily as multivibrators at 200 kilocycles. The synchronizing circuit of Fig. 11 was used. A 6AG7 tube inverts and clips the differentiated output of the first multivibrator tube so that in its plate circuit occur 200,000 1-microsecond pulses per second (see Fig. 18(f)). These pulses drive the grid of a 6AG7 first multiplier. A total multiplication of 528 times the crystal frequency is accomplished to give an output frequency of 105.6 megacycles. Voltage-regulator tubes maintain the multivibrator anode supply at 210 volts for stability.

A three-stage audio channel was provided with switching to give direct phase modulation, frequency modulation, or pre-emphasized frequency modulation. The effect of modulation throughout the multivibrator circuit is shown in Fig. 18(g), (h), (i), and (j).

The circuit of Fig. 16 is more desirable as a source of angular velocity modulation than that of Fig. 12. The larger part of the distortion to be encountered during modulation stems from the fact that the discharge curve of a capacitor is exponential rather than linear. For this reason, the linearity of modulation depends largely upon how narrow a section of this exponential curve can be utilized for maximum phase swing. It is desirable to use as large a coupling capacitance to the V_1 grid as possible, and as low a grid resistance as will still permit good operation. Separate bias adjustments were provided for both V_1 and V_2 grids for optimum adjustment.

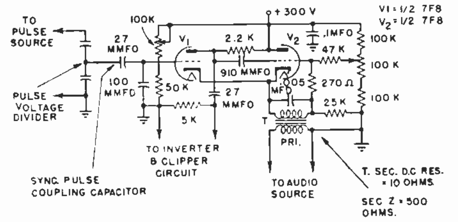

Fig. 16—A practical multivibrator circuit for 200- to 400-kilocycle operation which may be modulated by an audio voltage to produce angular-velocity-modulated negative pulses, the instantaneous phase angles of which follow faithfully the modulating-voltage conditions over relatively large deviations.

This circuit functions fundamentally as the previously described circuit with the exception that the anode of V_2 connects directly to the positive bus such that multivibrator coupling to V_1 is by means of the cathode circuit only.

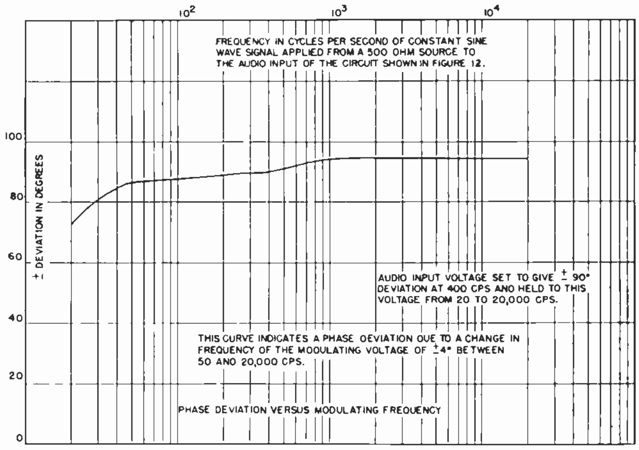

Fig. 17—Phase deviation versus modulating frequency.

Too high a synchronizing pulse has a tendency to feed through the multivibrator and occasionally trigger the multiplier chain at the wrong time. A capacitive voltage divider at the input to the synchronized grid provides a means of reducing this pulse to the desired value, which is just slightly greater than the peak value of the multivibrator output voltage (see Fig. 18(c)).

Like the previously described circuit, this circuit is adjusted to be just barely free running at a frequency somewhat lower than the operating frequency.

A root-mean-square voltage of 1 volt across the secondary of the modulation transformer will create a phase swing of approximately 180 degrees. This places very low requirements on the audio circuits.

NOISE MEASUREMENTS

Using a frequency-modulation receiver tuned to the transmitter output frequency, an unmodulated signal from a standard signal generator was used to drive fully the limiters of the receiver. The noise present on this signal was measured as 0.0022 volt root-mean-square. The transmitter of Fig. 15 was adjusted then to replace the standard generator signal and the noise voltage present under the same power input to the receiver was 0.0032 volt. Most of this appeared as random noise throughout the audio spectrum. These measurements

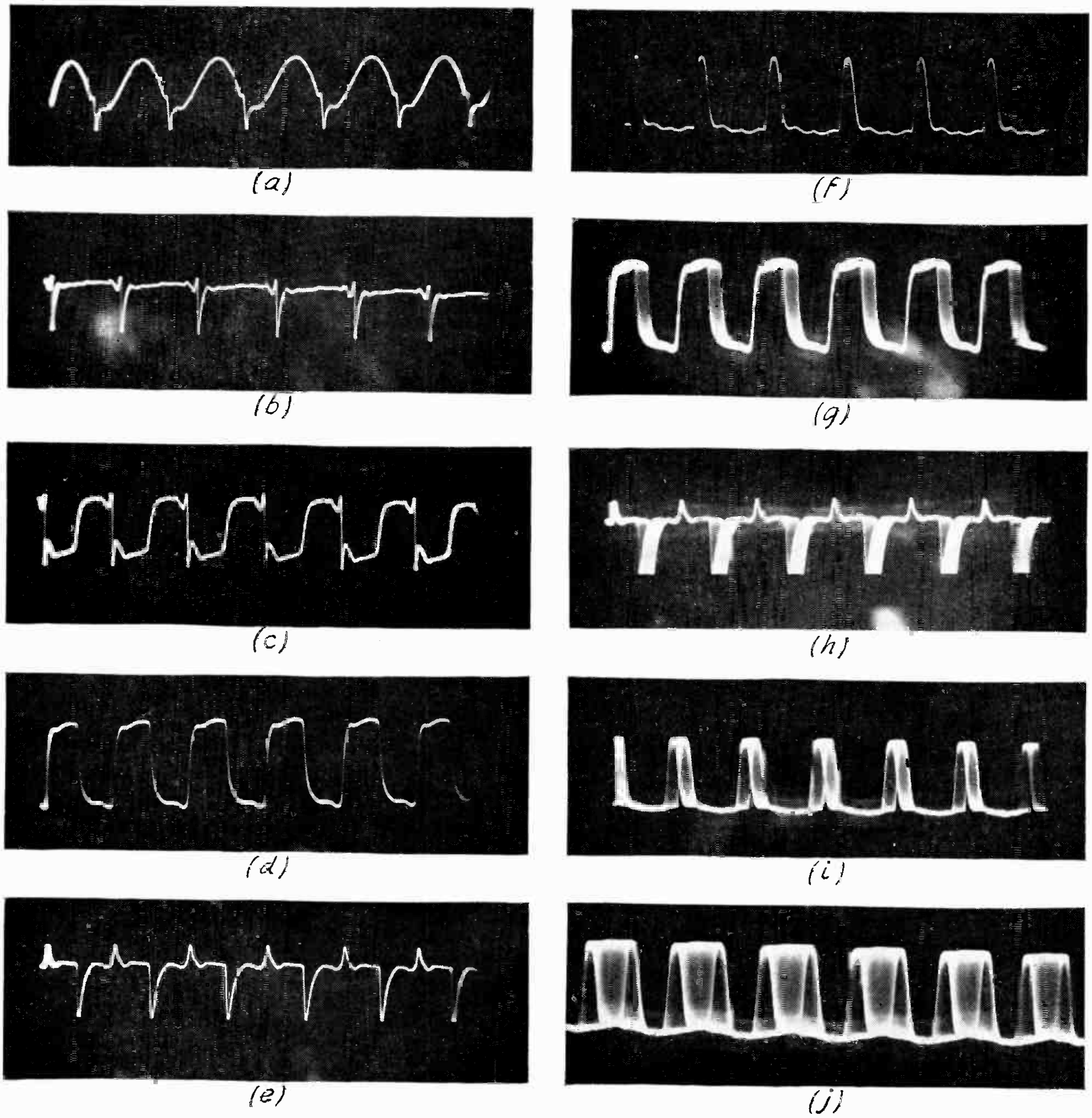

Fig. 18—Oscillograms taken from the transmitter shown in Fig. 15.
(a) Relationship between crystal-oscillator output and blocking-oscillator output pulse.
(b) Blocking-oscillator output after clipping. This pulse is applied to V_1 grid.
(c) Conditions on V_1 grid showing how the blocking-oscillator pulse initiates the multivibrator cycle.
(d) Conditions on V_1 anode.
(e) The differentiated output from V_1 anode as it appears on the first 6AG7 grid.
(f) The output of the first 6AG7. This positive pulse drives the first multiplier tube.
(g) Same as Fig. 18(d) but with modulation applied.
(h) Same as Fig. 18(e) but with modulation applied.
(i) Same as Fig. 18(f) but with modulation applied.
(j) Same as Fig. 18(f) but with wide modulation swing of approximately 200 degrees.

were made with the audio modulators in the transmitter disconnected. Applying 400-cycle modulation to the transmitter and keeping the receiver input at the same level resulted in approximately 65 decibels increase in output from 0.0032 volt while maintaining a 150-kilocycle swing at the transmitter output frequency. Since this noise is evenly distributed, these conditions remained constant throughout the usable audio spectrum.

Phase Deviation versus Modulating Frequency

The modulating voltage concerned in this measurement was applied directly to the modulator input circuit of the transmitter multivibrator (see Fig. 15). A low enough audio-oscillator output impedance was used to reduce any tendencies toward high-frequency attenuation. The audio output of the signal generator was set at a level to provide a 180-degree multivibrator swing at 400 cycles per second. The input voltage was then held constant and the frequency was varied between 20 and 20,000 cycles per second. The resultant phase deviation due to a change in modulating-voltage frequency, as shown in Fig. 17, was taken from measurements on an expanded oscilloscope time base. The circuit of Fig. 16 is linear throughout the range within 2 degrees, and is more desirable from this standpoint than the circuit of Fig. 12.

Fig. 18 includes oscillograms of the multivibrator grid and plate conditions. Fig. 18(c) particularly shows the relationship between the synchronizing pulse amplitude and the amplitude of the multivibrator grid voltage.

Amplitude Modulation in Multivibrator Output

The amplitude modulation present under all conditions in the multivibrator output is insignificant. Any appreciable amplitude variation would tend to create distortion during modulation.

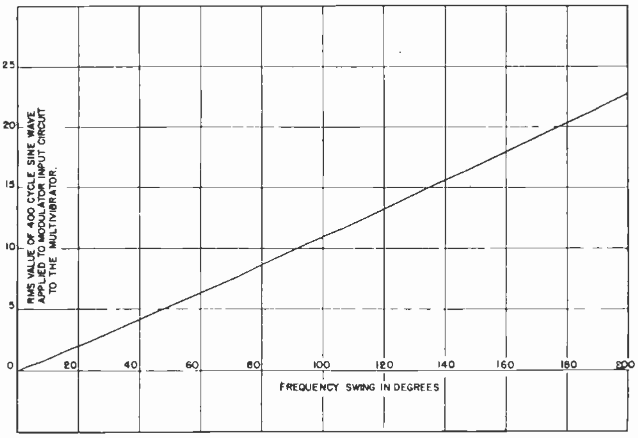

Fig. 19—Measured swing in degrees versus the 400-cycle modulating voltage required to produce the swing of the mutivibrator output used in the transmitter of Fig. 15.

Linearity of Modulation

The curve of Fig. 19 indicates the measured phase swing versus modulator-input volts at 400 cycles per second. It was accomplished in the following manner.

The oscilloscope was synchronized to show the radio-frequency wave of one of the multiplier stages. Modulation was then applied slowly to the transmitter. Each time a 360-degree swing at the multiplied frequency was indicated by an overlapping of the screen tracings, the voltage required to give this swing was tabulated.

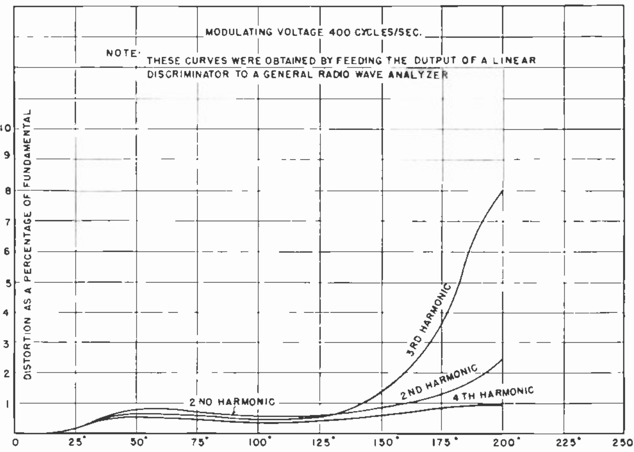

Fig. 20—The measured harmonic distortion of the circuit of Fig. 16 showing distortion percentage versus swing in degrees for a modulating frequency of 400 cycles. See Fig. 21 for test setup used in making measurements.

The curve of Fig. 19 was drawn from this information. Close examination will show that this is not a straight line but appears slightly exponential. This curve should not be used as a true indication of harmonic distortion, since the method used has some tendency to average the upper and lower phase swings. For measured distortion of the circuit of Fig. 16, see Fig. 20.

Harmonic Distortion of the Modulated Multivibrator Output

In order to determine the distortion present in the modulated multivibrator output signal, the test setup shown in Fig. 21 was used.

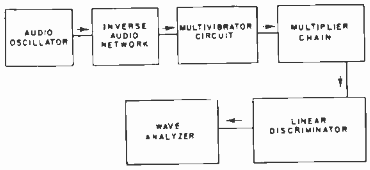

Fig. 21—Test setup for distortion measurements on the system.

An audio oscillator having a total harmonic distortion less than 0.1 per cent at 400 cycles was used to modulate the multivibrator of Fig. 16, the output of which was multiplied approximately one hundred times in a heavily damped multiplier chain, and fed to a linear discriminator.

This multiplication of 100 resulted in a maximum bandwidth at the discriminator of approximately 125 kilocycles for a multivibrator phase swing of 180 degrees. This was well within the measured limits of the linear characteristics of the discriminator used.

The discriminator output was fed directly to a General Radio wave analyzer. The distortion due to the audio oscillator, multiplier chain, and discriminator under these conditions is small, and the curves of Fig. 20 accurately indicate the measured harmonic distortion up to the fourth harmonic for a multivibrator swing of 200 degrees.

Due to the conditions set forth previously, the circuit of Fig. 12 has somewhat more distortion present than is shown here for the circuit of Fig. 16.

CONCLUSION

The modulated multivibrator, using pulse synchronization and pulse techniques to develop sine-wave output voltages which can be used to provide phase or frequency modulation of radio-frequency carriers, has applications in communications and broadcast transmission.

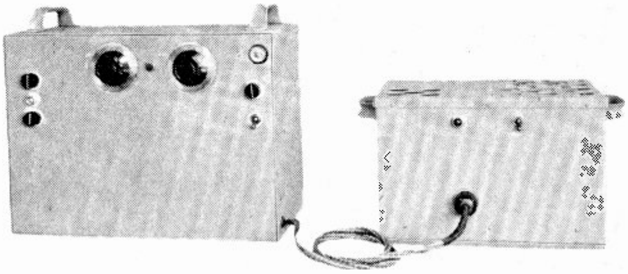

Fig. 22—Experimental transmitter (left) and power supply (right) used in the tests. The final power-amplifier input and output adjustments, plus the audio input circuit, are on the front panel

Several features characterize the system:

(1) no amplitude modulation due to phase modulation;

(2) phase swing versus modulation frequency is constant;

(3) a relatively small modulating voltage is required;

(4) relatively large phase swings may be accomplished with low distortion;

(5) frequency stabilization by means of crystal-controlled pulses;

(6) pulse initiation of the multiplier chain.

Three views of an experimental transmitter which was built around the system described are shown in Figs. 22, 23, and 24. The schematic of this transmitter is shown in Fig. 15.

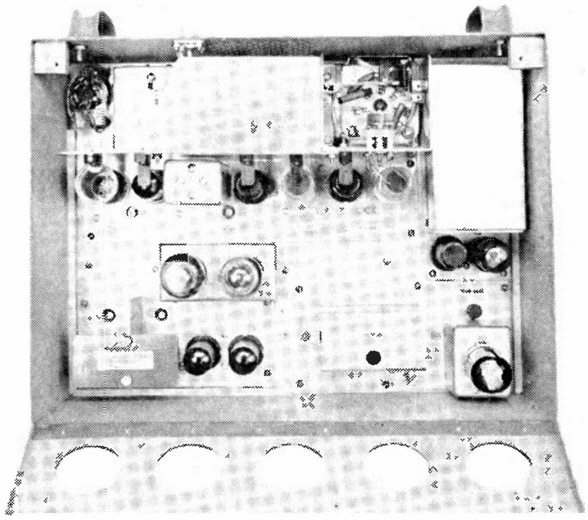

Fig. 23—Rear view of the transmitter with the panel open. The blocking oscillator is at the extreme lower right, while the two multivibrator tubes are to the left under the cover marked "phase adj."

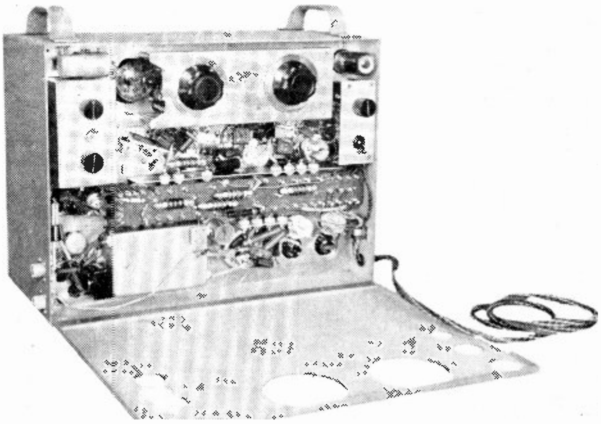

Fig. 24—Front view of the experimental transmitter with front panel open. The two-tube multivibrator circuit is housed within the shield at the lower left.

ACKNOWLEDGMENT

The author wishes to express his appreciation for the comments and suggestions made by A. C. Omberg and Dr. Harold Goldberg during the preparation of the original paper.

A Current Distribution for Broadside Arrays Which Optimizes the Relationship Between Beam Width and Side-Lobe Level[*]

C. L. DOLPH[†]

Summary—A one-parameter family of current distributions is derived for symmetric broadside arrays of equally spaced point sources energized in phase. For each value of the parameter, the corresponding current distribution gives rise to a pattern in which (1) all the side lobes are at the same level; and (2) the beam width to the first null is a minimum for all patterns arising from symmetric distributions of in-phase currents none of whose side lobes exceeds that level.

Design curves relating the value of the parameter to side-lobe level as well as the relative current values expressed as a function of side-lobe level are given for the cases of 8-, 12-, 16-, 20-, and 24-element linear arrays.

INTRODUCTION

FROM THE practical viewpoint, several things are desired of broadside antenna arrays. The beam should be as narrow as possible, the power gain a maximum, and the side lobes, if any, at a low level.

It is often a difficult matter to reconcile these demands. To illustrate, the gain may be made a maximum by feeding all of the point sources currents of equal magnitude and phase. Unfortunately, although it is true that this current distribution results in a narrow beam width, it also results in high side lobes of the order of 12 decibels down on the main lobe. In many applications it is more important to sacrifice some gain and beam width in order to achieve low-level side lobes. Several schemes have been suggested as a means of accomplishing this.

In particular, John Stone Stone[1] suggested that the point sources in an array of N elements be fed currents in phase with amplitudes proportional to the coefficients of a, b in the expansion $(a+b)^{N-1}$. The use of this so-called binomial expansion results in the total elimination of side lobes for spacings between the elements less than one-half wavelength but is in general impractical because of the increased beam width, loss of gain, and large current ratios demanded for large arrays.

S. A. Schelkunoff,[2,3] utilizing for the first time a correspondence between the nulls of the pattern and the roots of complex polynomials on the unit circle in the complex plane, was able to devise another scheme which did away, in part, with the above difficulties. By suitably spacing the roots of these polynomials on that portion of the unit circle traced out, he was able to derive many different types of pattern variation. In particular, by spacing these roots equally on the appropriate arc of the unit circle, he was always able to obtain an improvement in the side-lobe level over that of the uniform case for spacings less than one wave length. In this case, an algebraic identity led to formulas from which the current amplitudes and phases could be calculated. Since his treatment was carried out in the complex domain, it possessed the added advantage that it applied to both end-fire as well as broadside arrays. Although this method offers many advantages, it does not constitute a complete answer to this problem, since in certain applications the resulting improvement is inadequate.

This paper presents a third means of improving the pattern of linear arrays for the special broadside case in which the elements are fed in phase and are symmetrically arranged about the center of the array. The resultant current distribution across the array is based upon properties of the Tchebyscheff polynomials and offers, from the design standpoint, much greater control of the pattern. In particular, it possesses the following advantages:

(1) The current distribution can be calculated after either the side-lobe level or the position of the first null is specified.

(2) The current distribution is optimum in the sense that (a) if the side-lobe level is specified, the beam width is as narrow as possible (i.e., the number of degrees from the center of the beam to the first null is minimized), or (b) if the first null is specified, the side-lobe level is minimized.

(3) After either the side-lobe level or the position of the first null is specified, the position of the other nulls and of the side lobes can be found by simple calculation.

(4) All lobes other than the main beam and any other lobe arising from an in-phase condition of the same type as the main beam are at the same level.

(5) Detailed calculation of the pattern is unnecessary since the character of the pattern is completely known from the above properties.

GENERAL PATTERN CONSIDERATIONS

The discussion of linear broadside symmetric arrays of equally spaced point sources differs slightly in detail depending upon whether the arrays contain $2N$ or $(2N+1)$ elements. In the first case there is no radiating element at the center 0 of the array while in the second

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[1] John Stone Stone, United States Patents No. 1,643,323 and No. 1,715,433.

[2] S. A. Schelkunoff, "A mathematical theory of arrays," *Bell Sys. Tech. Jour.*, vol. 22, pp. 80–107; January, 1943.

[3] S. A. Schelkunoff, United States Patent No. 2,286,839.

case there is. These two different types with the appropriate values of I_n corresponding to the various point sources are shown in Figs. 1 and 2, respectively. In either case, let the center of the array 0 be taken as the phase reference point, let d denote the constant spacing

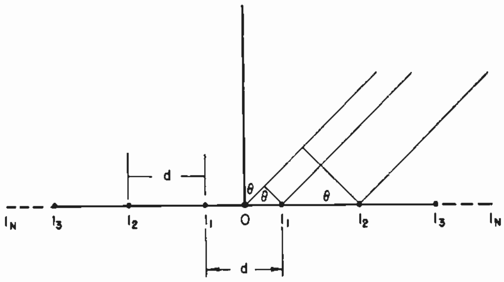

Fig. 1—Reference system for an array of $2N$ point sources.

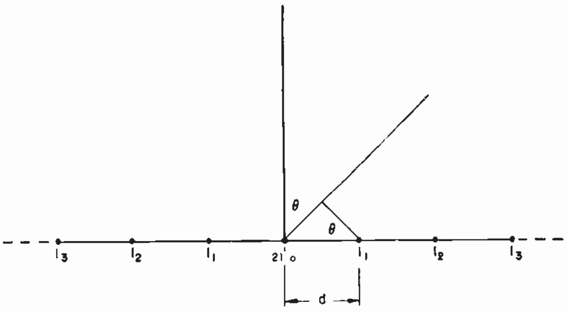

Fig. 2—Reference system for an array of $(2N+1)$ point sources.

between the point sources, let θ denote the angle between the direction of the field to distant point P and the normal to the array. Let I_n be proportional to the current fed into the point source located at a distance $(2n-1)d/2$ for Fig. 1 and at a distance of (nd) for Fig. 2. Let $2I_0$ denote the current fed into the center point source in Fig. 2. Then the field pattern of arrays of the type of Fig. 1 is well known to be proportional to

$$|E_{2N}(\theta)| = \left| \sum_{k=0}^{N-1} I_k \cos\left\{\frac{(2k+1)}{2}\left(\frac{2\pi d}{\lambda}\right)\sin\theta\right\}\right|. \qquad (1)$$

Similarly, the field pattern of arrays of the type of Fig. 2 is proportional to

$$|E_{2N+1}(\theta)| = \left| \sum_{k=0}^{N} I_k \cos\left\{k\left(\frac{2\pi d}{\lambda}\right)\sin\theta\right\}\right|. \qquad (2)$$

It must be emphasized again that (1) and (2) are valid only if all the currents are in phase along the array. Introducing the variable

$$u = \frac{d\pi}{\lambda}\sin\theta, \qquad (3)$$

(1) and (2) become respectively

$$|F_{2N}(u)| = \left| \sum_{k=0}^{N-1} I_k \cos(2k+1)u \right| \qquad (4)$$

and

$$|F_{2N+1}(u)| = \left| \sum_{k=0}^{N} I_k \cos(2ku) \right|. \qquad (5)$$

In either case, the discussion of (4) and (5) can be reduced to the consideration of polynomials of a real variable $x=\cos u$ on the real interval $-1 \leqq x \leqq 1$. To obtain the polynomial form, use is made of the fact that

$$e^{inu} = (\cos nu + i\sin nu) = (\cos u + i\sin u)^n$$

from which it follows that

$$\cos nu = \cos^n u - \binom{n}{2}\cos^{n-2} u \sin^2 u + \binom{n}{4}\cos^{n-4} u \sin^4 u + \cdots \qquad (6)$$

where

$$\binom{n}{k} = \frac{n!}{k!(n-k)!}.$$

If $\sin^2 u$ is replaced by $(1-\cos^2 u)$ it is apparent that $\cos nu$ is a polynomial of degree n in $x=\cos u$. It therefore follows that (4) and (5) are polynomials of degree $2N-1$ and $2N$ in x respectively, since they are merely sums of cosine polynomials. In fact, (4) is of the form $xP_{N-1}(x)^2$ where P_{N-1} is a polynomial of degree $(N-1)$ and (5) is of the form $Q_N(x^2)$ where Q_N is a polynomial of degree N.

Before obtaining explicit formulas for (4) and (5) in polynomial form, it is interesting to note a few fundamental properties which are consequences of this type of representation. The variable u is a universal parameter, the range of which is determined by the d/λ ratio. That is, if d/λ equals one, then the range of the variable u is clearly from $0 \leqq u \leqq \pi$. On the other hand, if d/λ is one half, then the range of u is $0 \leqq u \leqq \pi/2$. Since $\cos u$ in the range $0 \leqq u \leqq \pi/2$ is the negative of $\cos(\pi-u)$ in the range $\pi/2 \leqq u \leqq \pi$, it is clear that it is sufficient to compute either (4) or (5) in the range $0 \leqq u \leqq \pi/2$ and to use the recursion formula

$$|F(u)| = |F(\pi-u)| \qquad (7)$$

corresponding to (4) and (5) respectively in order to obtain the pattern as a function of u over the range $0 \leqq u \leqq \pi$. Similar formulas are obvious if d/λ exceeds one. However, the range $0 \leqq u \leqq \pi/2$ corresponds to half-wave spacing while the range $0 \leqq u \leqq \pi$ corresponds to full-wave spacing. Since a change in frequency is equivalent to a change in spacing, it follows that different portions of the fundamental pattern arising from the range $0 \leqq u \leqq \pi/2$ occur as the frequency is changed. In particular, it becomes apparent that a large lobe equal to the main beam will arise at $\theta=90$ degrees for wavelength spacing. Since for wavelength spacing, $u=\pi/2$ corresponds to $\theta=30$ degrees while $u=\pi$ corresponds to $\theta=90$ degrees, the fundamental pattern of θ occurs first in the 0- to 30-degree range and is then repeated in reverse order in the 30- to 90-degree range on θ giving rise to a lobe at 90 degrees roughly twice as broad as (although equal in magnitude to) the main beam. Since the only way to reduce this 90-degree lobe is by the use of highly directive elements, it is in general difficult to use spacing between the elements approaching one wavelength.

The introduction of the variable u makes clear the behavior of a broadside linear array over a band of frequencies provided that the current distribution remains unaltered as the frequency is shifted, a condition usually aimed at in design. That is, the portion of the fundamental pattern or multiples of it occurring in the range $0 \leqq u \leqq \pi/2$ merely changes as the frequency is shifted. In particular, if it is desired to calculate the performance of an array satisfying these conditions over a band of frequencies, it is only necessary to perform the calculations in terms of u over the basic range $0 \leqq u \leqq (\pi/2)$. The recursion formula (7), or others similar to it for values of d/λ greater than one, are then sufficient to give the pattern as a function of u corresponding to the d/λ ratio at the high end of the frequency band. Then it is only necessary to draw up a series of plots of (3) for the various d/λ ratios represented by the desired frequencies in the band and use this with the appropriate portion of the pattern as a function of u for the high end in order to obtain the complete pattern over the band.

In order to obtain explicitly polynomial representations in terms of $x = \cos u$ for (4) and (5), it is first necessary to verify that (6) implies that

$$\cos (2n+1)u = \sum_{m=0}^{n} A_{2m+1}{}^{2n+1} x^{2m+1} \tag{8}$$

where

$$A_{2m+1}{}^{2n+1} = (-1)^{n-m} \sum_{p=n-m}^{n} \binom{p}{p-n+m} \binom{2n+1}{2p} \tag{9}$$

and that

$$\cos 2nu = \sum_{m=0}^{n} A_{2m}{}^{2n} x^{2m} \tag{10}$$

where

$$A_{2m}{}^{2n} = (-1)^{n-m} \sum_{p=n-m}^{n} \binom{p}{p-n+m} \binom{2n}{2p}. \tag{11}$$

If (8) and (10) are inserted into (4) and (5) respectively, they become

$$G_{2N-1}(x) = \sum_{k=1}^{N} I_k \left\{ \sum_{m=1}^{k} A_{2m-1}{}^{2k-1} x^{2m-1} \right\}$$

and

$$G_{2N}(x) = \sum_{k=0}^{N} I_k \left\{ \sum_{m=0}^{k} A_{2m}{}^{2k} x^{2m} \right\}.$$

Since these last two equations involve finite double summations they can easily be rearranged to become respectively

$$G_{2N-1}(x) = \sum_{q=1}^{N} \sum_{k=q}^{N} I_k A_{2q-1}{}^{2k-1} x^{2q-1} \tag{12}$$

and

$$G_{2N}(x) = \sum_{q=0}^{N} \sum_{k=q}^{N} I_k A_{2q}{}^{2k} x^{2q}. \tag{13}$$

The difference between the lower limits in the outer summation sign of (12) and (13) arises because of the presence of a radiating element at the center of the array in the case of (13).

Equations (12) and (13) and their first derivatives with respect to u can be used to obtain the positions of the nulls and the side lobes of the radiation pattern of any symmetric in-phase broadside array. It is often true that the analytical processes involved are tedious if the number of elements in the array is large. The introduction of $y = x^2$ will materially simplify the analysis in all cases, however.

It is interesting to examine this type of representation for the case of the four-element array. This case exhibits all of the main points involved and is simple enough so that the mathematics does not present any difficulties. For a four-element array (4) becomes

$$F_4(u) = I_1 \cos u + I_2 \cos 3u.$$

Since $\cos 3u = 4 \cos^3 u - 3 \cos u$, this can be written as

$$G_3(x) = F_4(u) = x\{4I_2x^2 + (I_1 - 3I_2)\}$$

where $$x = \cos u, \qquad -1 \leqq x \leqq 1.$$

The nulls therefore occur at $x = 0$ and at

$$x_0 = \pm \sqrt{\frac{3 - \dfrac{I_1}{I_2}}{4}}. \tag{14}$$

The position of the side lobes are given by the roots of $dG_3(x)/du = 0$. Thus the position of the main beam and the other in-phase lobes are given by

$$dx/du = -\sin u = 0$$

and the positions of the other side lobes by

$$\bar{x} = \pm \sqrt{\frac{3 - \dfrac{I_1}{I_2}}{12}}.$$

At these points $G_3(x)$ attains the value

$$|G_3(\bar{x})| = \frac{\sqrt{3}}{9} |I_2| \left| \left(3 - \frac{I_1}{I_2}\right)^{3/2} \right|.$$

The beam width is essentially given by the position of the first null which (14) determines. In this simple example, then, the beam width, the position of the side lobes, and the height or level of the side lobes are all functions of the same quantity, namely,

$$\left(3 - \frac{I_1}{I_2}\right).$$

The range of the ratio I_1/I_2 from $1 \leqq I_1/I_2 \leqq 3$ covers the range from the uniform distribution to the binomial. As the ratio increases over this range, it becomes apparent that the first null moves toward zero, so that the beam broadens and the side-lobe level drops until at the value of three the side lobes vanish altogether. It is also clear that the beam can be made narrower than in the uniform case merely by choosing the range of I_1/I_2 from $0 \leqq I_1/I_2 \leqq 1$. The gain is of course a maximum for the uniform case.

It should be remarked again that, for larger arrays, it is in general impossible to devise physical means of achieving the range of current distribution from the uniform case to the binomial one because of the very large current ratios which become necessary in the latter case.

THE OPTIMUM CURRENT DISTRIBUTION

The distribution which will be deduced in this section has many properties in common with the distribution just discussed. As the taper is increased, the beam slowly broadens and the side-lobe level drops. It, however, possesses one great advantage: it is optimum in the sense that, once the side-lobe level is specified, the beam width (distance to first null) will be as small as possible; or, if the beam width is specified, the side-lobe level will be a minimum. Before demonstrating that this is always possible, it will be convenient to consider the nonnormalized Tchebyscheff polynomials. These are defined[4] by

$$T_n(z) = \cos (n \arc \cos z). \tag{15}$$

To see that these are indeed polynomials of degree n in z, set $\phi = \arc \cos z$ and use (6). The nulls of these polynomials are given by the roots of $\cos n\phi = 0$, or by

$$\phi_k{}^0 = (2k-1)\pi/2n, \qquad k = 1, 2, \cdots, n. \tag{16}$$

Further, $T_n'(z) = 0$ whenever $\sin n\phi = 0$, or when

$$\bar{\phi}_k = k\pi/n, \qquad k = 1, 2, \cdots, n. \tag{17}$$

At the points $\bar{\phi}_k$, let $\bar{z}_k = \cos \bar{\phi}_k$. Then $\left| T_n(\bar{z}_k) \right| = 1$. If one uses (15) as the definition, then clearly $-1 \leqq z \leqq 1$. However, considered as a polynomial in z, $T_n(z)$ exists for all z, $-\infty \leqq z \leqq \infty$. Moreover, if $z > 1$, then $T_n(z)$ is monotonically increasing, and if $z < -1$, it is either monotonically increasing or decreasing depending upon whether n is even or odd. Furthermore, $T_n{}^{(k)}(z)$ can only vanish for any k, $(k = 1, 2, \cdots, n)$ in the interval between $-1 \leqq z \leqq 1$. This is obviously true by induction, since $T_n(z)$ has n roots in this interval and $T_n'(z)$ has $n-1$ roots contained within the n roots of $T_n(z)$, etc.

Equations (8), (9), (10), and (11) lead to the following expressions, respectively:

$$T_{2N-1}(z) = \sum_{q=1}^{N} A_{2q-1}{}^{2N-1} z^{2q-1}; \quad -\infty \leqq z \leqq \infty \tag{18}$$

$$T_{2N}(z) = \sum_{q=0}^{N} A_{2q}{}^{2N} z^{2q}; \quad -\infty \leqq z \leqq \infty. \tag{19}$$

Now if the range of z is restricted to $-z_0 \leqq z \leqq z_0$, then clearly (18) and (19) can be reduced to polynomials of the form of (12) and (13) by introduction of the scale contraction given by $x = z/z_0$, whereas before $x = \cos u$. Written in terms of x, $-1 \leqq x \leqq 1$, (18) and (19) become

$$T_{2N-1}(z_0 x) = \sum_{q=1}^{N} A_{2q-1}{}^{2N-1} z_0{}^{2q-1} x^{2q-1} \tag{20}$$

and

$$T_{2N}(z_0 x) = \sum_{q=0}^{N} A_{2q}{}^{2N} z_0{}^{2q} x^{2q}. \tag{21}$$

Now if (20) is equated to (12), the following set of equations is obtained:

$$\sum_{k=q}^{N} I_k A_{2q-1}{}^{2k-1} = A_{2q-1}{}^{2N-1} z_0{}^{2q-1}, \quad q = 1, \cdots, N.$$

These may be written in the form

$$I_q = \frac{1}{A_{2q-1}{}^{2q-1}} \left\{ A_{2q-1}{}^{2N-1} z_0{}^{2q-1} - \sum_{k=q+1}^{N} I_k A_{2q-1}{}^{2k-1} \right\}. \tag{22}$$

Similarly equating (21) to (13) yields

$$I_q = \frac{1}{A_{2q}{}^{2q}} \left\{ A_{2q}{}^{2N} z_0{}^{2q} - \sum_{k=q+1}^{N} I_k A_{2q}{}^{2k} \right\}. \tag{23}$$

It is clear that (22) and (23) can be solved for I_q, $q = 1, \cdots, N$ in terms of z_0 by a step-wise process starting from $q = N$.

Thus, for each value of z_0, the pattern as given by (12) or (13) can be made to agree with the pattern as given by (18) or (19). However, the characteristics of the latter expressions are completely known from the above discussion of the Tchebyscheff polynomials.

The parameter z_0 can be chosen in either of two ways: (1) the side-lobe level can be specified, or (2) the position of the first null can be specified.

In the first case, if the main-beam-to-side-lobe ratio is chosen to be $r/1$, it is necessary that z_0 satisfy the relation

$$T_M(z_0) = r; \qquad z_0 \geqq \cos (\pi/2M) \tag{24}$$

where

$M = 2N-1$ for an array of $2N$ elements
$= 2N$ for an array of $2N+1$ elements.

Once this value of z_0 has been determined and the current distribution computed from either (22) or (23), the pattern characteristics are completely known, since

(a) The side lobes are all equal and down on the main lobe in the ratio $1/r$.

(b) The nulls of the pattern are given by

$$u = \arc \cos \left[(\cos \phi_k{}^0)/z_0 \right]; \quad k = 1, 2, \cdots, N \tag{25}$$

where $\phi_k{}^0$ are given by (16) and u by (3).

(c) The positions of the side lobes are given by

$$u = \arc \cos \left[(\cos \bar{\phi}_k)/z_0 \right]; \quad k = 1, 2, \cdots, N \tag{26}$$

where $\bar{\phi}_k$ is given by (17).

(d) The pattern between the nulls is given by

$$F(u) = \cos \left\{ M \arc \cos (z_0 \cos u) \right\} \tag{27}$$

or by

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[4] Courant-Hilbert, "Methoden der Mathematischen Physik," vol. 1, pp. 75–76, Julius Springer, Berlin, 1931, and Interscience Publishers, Inc., New York, N. Y., 1943.

$$E(\theta) = \cos\left\{M \arccos\left[z_0 \cos\left(\frac{\pi d}{\lambda}\sin\theta\right)\right]\right\}.$$

In the second case, if the first null is specified as θ_0, it is necessary to compute x_1^0 from

$$x_1^0 = \cos u_1^0 = \cos\left(\frac{\pi d}{\lambda}\sin\theta_0\right)$$

and to choose z_0 from the relation

$$z_0 = \frac{1}{x_1^0}\cos\frac{\pi}{2M} \tag{28}$$

so that $T_M(z_0x) = T_M\left[\left(\cos\frac{\pi}{2M}\right)x/x_1^0\right]$

will possess the necessary null at x_1^0. In this case, also, the pattern is completely characterized once the current distribution has been determined, since the main-beam-to-side-lobe ratio is $(\sum I_k):1$ and since the nulls, side-lobe positions, and pattern between the nulls are again given by (25), (26), and (27), respectively, when the value of z_0 from (28) is inserted.

The distribution by the solutions of (22) and (23) possesses the following important optimum property in addition to the above advantages: (1) *If the side-lobe level is specified, the beam width (i.e., the number of degrees to the first null) is minimized*; (2) *if the first null is specified, the side-lobe level is minimized.*

The proof of these statements is contained in the following theorem, which is clearly applicable to polynomials of the form (12) and (13).

Theorem:[4] Let $C(a)$ be a class of polynomials with real coefficients and of degree n having all of its roots in the interval $(-1, 1)$ such that

(1) If a polynomial $P(x)$ is in the class $C(a)$, then

$$P(x) = -P(-x) \quad \text{if} \quad n \text{ is odd}$$
$$P(x) = P(-x) \quad \text{if} \quad n \text{ is even}$$
$$P(1) = 1.$$

(2) If a polynomial $P(x)$ is in the class $C(a)$ and x_0 is its largest root (i.e., $|x_0|$ is a maximum among all the roots), then

$$|P(x)| \leqq a \quad \text{whenever} \quad |x| \leqq |x_0| \leqq 1.$$

Then

(1) There exists a polynomial $M(x)$ in $C(a)$ which maximizes $|x_0|$.

(2) The polynomial $M(x)$ is characterized by the fact that it just touches the lines $y = \pm a$ at $n-1$ points x_k within $|x| \leqq x_0$.

Specifically, $M(x) = aT_n(z_0x)$ where z_0 satisfies the relations

$$T_n(z_0) = \frac{1}{a}; \qquad z_0 \geqq \cos\left(\frac{\pi}{2n}\right).$$

To prove this theorem, consider any polynomial in the class $C(a)$ which is not $M(x)$. Let x_0 be its largest root. Find y_0 from the relation

$$y_0 = \frac{\cos\left(\frac{\pi}{2n}\right)}{x_0} = z_1^0/x_0, \quad \text{where} \quad z_1^0 = \cos\left(\frac{\pi}{2n}\right)$$

and construct the polynomial [which may or may not belong to $C(a)$]

$$Q(x) = AT_n\left(\frac{z_1^0x}{x_0}\right);$$

$Q(x)$ therefore also possesses x_0 as the largest root. Determine A so that $Q(1)=1$; then $Q(-1)=-1$ if n is odd and $Q(-1)=1$ if n is even. $Q(x)$ is therefore a polynomial which has the same largest root at $P(x)$ and which, since it is just a modified Tchebyscheff polynomial, is such that max $|Q(x)|$ is attained $n-1$ times between $-x_0 \leqq x \leqq x_0$.

Now it will be shown that

$$\max|Q(x)| < \max|P(x)|$$

when $|x| \leqq |x_0|$ so that $Q(x)$ belongs to $C(b)$ contained in $C(a)$. Assume the contrary; namely, that

$$\max|Q(x)| \geqq \max|P(x)| \tag{29}$$

when $|x| \leqq |x_0|$. Form the difference polynomial

$$D(x) = Q(x) - P(x)$$

which is, *at most*, of degree n. However, by construction of $Q(x)$

$$D(1) = 0, \qquad D(-1) = 0, \qquad D(x_0) = 0.$$

Let x_k, $k = 1, 2, n-1$, denote the $(n-1)$ points where $Q(x)$ attains its maximum value in the interval $|x| \leqq |x_0|$, and evaluate $D(x)$ at these points under the assumption (29), so that

$$D(x_1) \leqq 0,\ D(x_2) \geqq 0, \cdots, D(x_{n-1})\substack{\geqq 0 \\ \leqq 0}.$$

Thus $D(x)$ experiences $(n-2)$ changes in sign between $(-x_0, x_0)$ and consequently it must possess $(n-2)$ additional roots in this interval. This makes the total number of roots $(n+1)$, which is obviously impossible, since $D(x)$ is, at most, of degree n. Consequently, (29) is false and it therefore follows that

$$b = \max|Q(x)| < \max|P(x)| \leqq a \text{ when } |x| \leqq |x_0| < 1.$$

Consequently, unless $P(x)$ is $M(x)$, a polynomial $Q(x)$ can always be constructed possessing the same largest root as $P(x)$ and belonging to a class of polynomials $C(b)$ which is contained in the class $C(a)$. It therefore follows that $M(x)$ is the one polynomial in $C(a)$ which maximizes $|x_0|$.

Physically speaking, the improvement in beam width given by the above type of distribution results from the raising of the side lobes at wide angles to the level of those near the main beam. From a practical viewpoint, this is inconsequential for two reasons: (1) if the side lobes are sufficiently low in level everywhere, it is of no importance that they fall off with increasing angle, and (2) the primary patterns of many types of radiating elements fall off with increasing angle so that the final wide-angle lobes would be at a lower level than those close to the beam.

Theoretically at any rate, (2) suggests that a still greater improvement in beam width for a given side-lobe level might be obtained by devising a current distribution for the point sources in which the side lobes increased in magnitude with increasing angle in just the right proportion so that the superposition of the array pattern and that of the primary radiator would result in an over-all pattern possessing side lobes at the desired constant level.

ESTIMATION OF BEAM WIDTH TO OTHER THAN THE FIRST NULL

An estimate of the beam width to the half-power (3-decibel points) or to any other decibel point can be made readily if a plot of the side-lobe-level versus z_0 from (24) has been made over the appropriate range. Knowing the side-lobe level L in decibels, find from the curves of this type (see Appendix IV) the z_0 corresponding to this level. Also read from these curves the z_0' corresponding to $(L-R)$, where R is the number of decibels down on the maximum where the beam width is desired. The beam width in terms of u is then given by

$$u = \text{arc cos}\,(z_0'/z_0). \tag{30}$$

Again a plot of (3) can be used to give the beam width R decibels down on the maximum in terms of deviation from the normal to the array θ, or θ may be found directly from

$$\theta = \text{arc sin}\left\{\frac{\lambda}{\pi d}\,\text{arc cos}\,(z_0'/z_0)\right\}. \tag{31}$$

EXAMPLES OF THE METHOD

A linear, in-phase, symmetric array consisting of eight elements will first be used by way of illustration. In this case (4) becomes the following: (The absolute value sign may be omitted.)

$$F_8(u) = I_1 \cos u + I_2 \cos 3u + I_3 \cos 5u + I_4 \cos 7u.$$

From this (see Appendix I) it is readily deduced that

$$\begin{aligned} G_7(x) = x\{&64I_4x^6 + (16I_3 - 112I_4)x^4 \\ &+ x^2(4I_2 - 20I_3 + 56I_4) \\ &+ [I_1 - 3I_2 + 5I_3 - 7I_4]\}. \end{aligned} \tag{32}$$

Furthermore, from Appendix I, if $\phi = \text{arc cos}\, z$, then

$$T_7(z) = \begin{cases} z[64z^6 - 112z^4 + 56z^2 - 7] \text{ if } -\infty \leqq z \leqq \infty \\ \cos 7\phi \quad \text{if } |z| \leqq 1. \end{cases} \tag{33}$$

The following set of equations corresponding to (22) result when $G_7(x)$ is equated to $T_7(z_0x)$:

$$\begin{aligned} I_4 &= z_0^7 \\ I_3 &= 7I_4 - 7z_0^5 \\ I_2 &= 5I_3 - 14I_4 + 14z_0^3 \\ I_1 &= 3I_2 - 5I_3 + 7I_4 - 7z_0. \end{aligned} \tag{34}$$

Thus, once z_0 is determined from (24) or (28), the currents can be computed.

The pattern as a function of x is shown in Fig. 3 for $z_0 = 1.14$. This, as may be seen by referring to the plot of side-lobe level versus z_0 as given for an array of eight elements in Appendix IV, corresponds to a side-lobe level of 25.8 decibels.

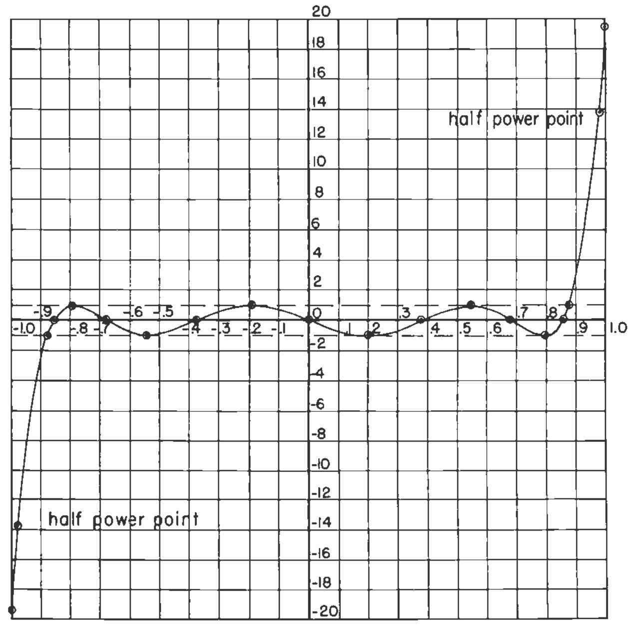

Fig. 3—T_7 (Z_0) versus x. "The optimum pattern" as a function of x for an 8-element array with a 25.8-decibel side-lobe level. $z_0 = 1.14$.

This same pattern, replotted as a function of u, is shown in Fig. 4.

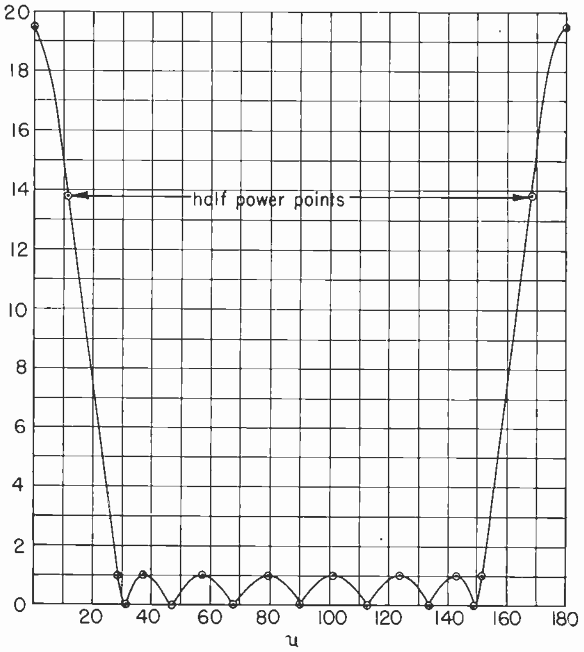

Fig. 4—$|F(u)| = |T_7(z_0 \cos u)|$ versus u for $z_0 = 1.14$. "The optimum pattern" as a function of u for an 8-element array with a 25.8-decibel side-lobe level.

Finally, this pattern is again replotted in terms of the physically measurable angle θ for the two spacing wavelength ratios (d/λ) of one and one half in Fig. 5.

In all of these illustrations, only the circled points represent computed values. The data from which these curves were drawn are summarized below in Table I, in which

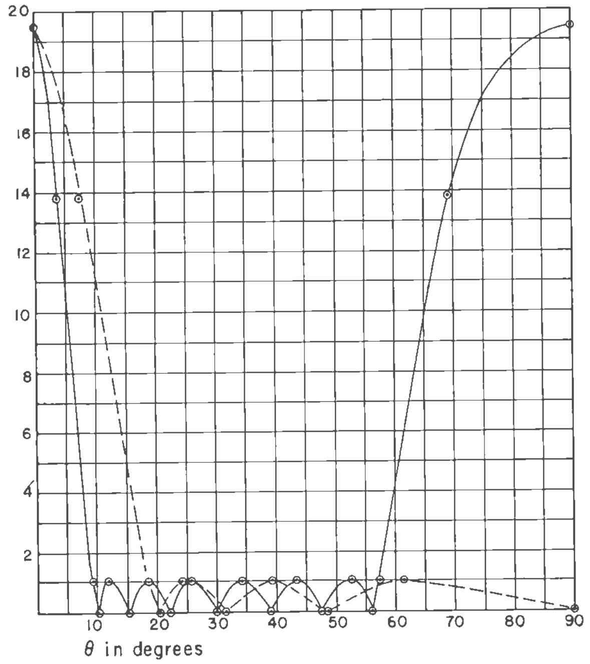

Fig. 5—$|E(\theta)| = |T_7[z_0 \cos \pi d/\lambda \sin \theta)]|$ versus θ for $z_0 = 1.14$. "The optimum pattern" as a function of θ for half-wave and full-wave spacing for an 8-element array with a 25.8-decibel side-lobe level.

——— $d/\lambda = 1$

- - - - - - $d/\lambda = \frac{1}{2}$

rows one and two give the position of the nulls as a function of ϕ_k^0 from (16);

row three gives the computed values of the nulls as a function of $\cos \phi_k^0$;

row four gives the nulls, as function of x corresponding to the scale contraction associated with $z_0 = 1.14$;

row five gives the position of the nulls as a function of u as obtained from $x = \cos u$ and equation (3):

rows six and seven give the position of the nulls as a function of θ for $d/\lambda = 1$ and $d/\lambda = \frac{1}{2}$, respectively.

The second half of the table summarizes this same information for the position of the side lobes. In it, the starting point, row eight, is obtained from (17).

Column I gives the recursion formulas which were used to compute the table to the right of the first double vertical line in each half from the values to the left of it.

In addition to the above values, all the figures have plotted on them the maximum points, the estimated half-power points, and the extreme points where the beam attains the side-lobe level in its ascent to a maximum value.

The maximum points correspond to the fact that a 25.8-decibel side-lobe level corresponds to a main-beam-to-side-lobe-level ratio of 19.45.

The estimated half-power points of value (0.707) times (19.48) or 13.8, were located by means of (30), (31), and the curve from Appendix IV referred to above. That is, the value of $z_0' = 1.116$ corresponding to 22.8 decibels (3 decibels down on the main-beam-to-side-lobe-level ratio) was obtained from this curve.

TABLE I
8-ELEMENT ARRAY

		$z_0 = 1.14$					Side-Lobe Level = 25.8 decibels			
		A k	B 1	C 2	D 3	E 4	F 5	G 6	H 7	I
Null Positions	1	ϕ_k^0	$\frac{\pi}{14}$	$\frac{3\pi}{14}$	$\frac{5\pi}{14}$	$\frac{7\pi}{14}$	$\frac{9\pi}{14}$	$\frac{11\pi}{14}$	$\frac{13\pi}{14}$	
	2		12.85 degrees	38.6 degrees	64.3 degrees	90 degrees	115.7 degrees	141.4 degrees	167.15 degrees	$\cos \phi = -\cos (\pi - \phi)$
	3	$z_k^0 = \cos \phi_k^0$	0.9750	0.7815	0.4337	0	−0.4337	−0.7815	−0.9750	
	4	$x_k^0 = z_k^0/z_0$	0.854	0.685	0.380	0	−0.380	−0.685	−0.854	
	5	$u_k^0 = \text{arc cos } x_k^0$	31.35 degrees	46.7 degrees	67.5 degrees	90 degrees	112.5 degrees	133.3 degrees	148.65 degrees	$\|F(u)\| = \|F(\pi - u)\|$
	6 $d/\lambda = 1$	$\theta = \text{arc sin } \frac{\lambda u}{\pi d}$	10 degrees	15.1 degrees	22.1 degrees	30 degrees	38.7 degrees	47.4 degrees	55.7 degrees	
	7 $d/\lambda = \frac{1}{2}$	$\theta = \text{arc sin } \frac{\lambda u}{\pi d}$	20.4 degrees	31.3 degrees	48.6 degrees	90 degrees				
Side-Lobe Positions	8	$\bar{\phi}_k$	$\frac{\pi}{7}$	$\frac{2\pi}{7}$	$\frac{3\pi}{7}$	$\frac{4\pi}{7}$	$\frac{5\pi}{7}$	$\frac{6\pi}{7}$	0 π	
			25.7 degrees	51.5 degrees	77.2 degrees	102.8 degrees	128.5 degrees	154.3 degrees	0/180 degrees	
	9	$\bar{z}_k = \cos \phi_k$	0.9011	0.6225	0.2215	−0.2215	−0.6225	−0.9011	+1 −1	$\cos \phi = -\cos (\pi - \phi)$
	10	$\bar{x}_k = \frac{\bar{z}_k}{z_0}$	0.790	0.545	0.194	−0.194	−0.545	−0.790	0.876 −0.876	
	11	$\bar{u}_k = \text{arc cos } \bar{x}_k$	36.8 degrees	56.9 degrees	78.8 degrees	101.2 degrees	123.1 degrees	143.2 degrees	28.8 degrees 151.2 degrees	$\|F(u)\| = \|F(\pi - u)\|$
	12 $d/\lambda = 1$	$\theta = \text{arc sin } \frac{\lambda u}{\pi d}$	11.8 degrees	18.4 degrees	25.9 degrees	34.1 degrees	43.2 degrees	52.7 degrees	9.2 degrees 57.1 degrees	
	13 $d/\lambda = \frac{1}{2}$	$\theta = \text{arc sin } \frac{\lambda u}{\pi d}$	24.2 degrees	39.2 degrees	61.1 degrees				18.7 degrees	

This locates the half-power points in terms of x at $x = \pm 1.116/1.14 = \pm 0.9789$. Since $u = \text{arc cos } x$, this gives the location in terms of u at 11.8 and 168.2 degrees, respectively. For $d/\lambda = 1$, these in turn correspond to $\theta = 3.7$ and 69.2 degrees, respectively, giving an estimated total beam width of 7.4 degrees at the half-power points. For $d/\lambda = \frac{1}{2}$, the above values of u give a value of $\theta = 7.5$ degrees, or an estimated total beam width at the half-power points of 15 degrees.

Finally, it is clear from the general theory that the side-lobe level will be reached at extreme points corresponding to $\phi = 0, \pi$. The interpretation of these values in the x, u, and θ variables is carried through in column H in rows eight through thirteen.

It must be re-emphasized that, from the design viewpoint, all of the calculations tabulated in Table I are unnecessary, except perhaps the determination of the beam width at the half-power points. That is, practically, if the current distribution can be chosen to place the side lobe at an arbitrarily low level, it does not matter at all where they or the nulls occur. Table I is merely inserted as an aid to the understanding of the preceding theory, and for the sake of completeness.

LIMITING CASES OF THE OPTIMUM DISTRIBUTION

It is interesting to examine the design equation (34) for the two limiting cases of unit z_0 and infinite z_0. In order to make this examination, it is first necessary to rewrite all of the currents as functions of z_0. If this is done, (34) becomes

$$I_4 = z_0^7$$

$$I_3 = 7z_0^7 - 7z_0^5$$

$$I_2 = 21z_0^7 - 35z_0^5 + 14z_0^3$$

$$I = 35z_0^7 - 70z_0^5 + 42z_0^3 - 7z_0.$$

Letting z_0 assume the value unity, all the I_k's vanish except I_4, which becomes unity, so that the pattern is proportional, by (3), to cos $7u$. In this case the side-lobe level is equal to that of the main beam. This result is, of course, expected because of the construction of this distribution.

In order to examine the case of infinite z_0, consider the set of equations obtained by dividing the above set by I_4.

$$I_4/I_4 = 1$$

$$I_3/I_4 = 7 - 7/z_0^2$$

$$I_2/I_4 = 21 - 35/z_0^2 + 14/z_0^4$$

$$I_1/I_4 = 35 - 70/z_0^2 + 42/z_0^4 - 7/z_0^6.$$

Letting z_0 approach infinity, the currents take on the ratios 1, 7, 21, 35. These are recognized as the binomial coefficients of the expansion $(a+b)^7$. In this case the pattern is well known to be proportional to $(\cos u)^7$ and contains no side lobes whenever u is restricted to the range $0 \leqq u \leqq (\pi/2)$. Thus, it is apparent that the above theory covers the entire range of side-lobe levels. It should be added that, whenever design equations are derived, these two limiting cases can be used as a convenient check.

Similarly, a seven-element array will be used as an illustration. In this case (5) becomes

$$F_7(u) = I_0 + I_1 \cos 2u + I_2 \cos 4u + I_3 \cos 6u.$$

Letting $x = \cos u$ and using (13), this can be written as

$$G_6(x) = 32I_3x^6 + (8I_2 - 48I_3)x^4 + (2I_1 - 8I_2 + 18I_3)x^2 + (I_0 - I_1 + I_2 - I_3),$$

since

$$\cos 2u = 2x^2 - 1$$

$$\cos 4u = 8x^4 - 8x^2 + 1$$

$$\cos 6u = 32x^6 - 48x^4 + 18x^2 - 1.$$

Similarly, if $\phi = \text{arc cos } z$

$$T_6(z) = 32z^6 - 48z^4 + 18z^2 - 1; \quad -\infty \leqq z \leqq \infty$$
$$= \cos 6\phi; \quad -1 \leqq z \leqq 1$$

so that if the identification corresponding to (24) or (28) is made, the following design equations are obtained:

$$I_3 = z_0^6$$

$$I_2 = 6I_3 - 6z_0^4$$

$$I_1 = 4I_2 - 9I_3 + 9z_0^2$$

$$I_0 = I_1 - I_2 + I_3 - 1.$$

Since the construction of a table like the one given for the eight-element array proceeds almost as before and results in figures similar to 3, 4, and 5, no further details will be given here for the seven-element case. Moreover, because the author has been involved in the design of linear arrays of $2N$ elements exclusively, the detailed calculations and curves to be found in the appendixes are given for this case only.

It should be remarked that, if the current ratios are computed by formulas like (34) and those in Appendix III, and not normalized, then

$$20 \log \sum I_k$$

gives the side-lobe level in decibels at once.

Appendix I contains the Tchebyscheff polynomials of the form $\cos (2n-1)\phi$ for $n = 1, \cdots, 12$.

Appendix II gives the formula for $G_{23}(x)$ for an array of 24 elements. The appropriate formulas for shorter arrays of $2N$ elements can be deduced instantly merely by setting the excess I_k equal to zero.

Appendix III contains the design equations similar to (34) for this type of distribution of arrays consisting of 12, 16, 20, and 24 elements.

Appendix IV gives design curves for arrays of this type consisting of 8, 12, 16, 20, and 24 elements. These curves are given for a range of 26- to 40-decibel side-lobe level and show

(1) the variation of the side-lobe level with z_0;

(2) the variation of the currents as a function of the side-lobe level;

(3) the reduction in power gain from a uniform array consisting of the same number of elements as a function

of the side-lobe level for 8-, 12-, and 24-element arrays under the assumption that the mutual impedances between the elements are zero.

In this, the power-gain reduction from a uniform array is given by the well-known and easily derivable formula

$$G = \frac{\left(\sum_1^N I_k\right)^2}{N\left(\sum_1^N I_k^2\right)}$$

for symmetrical arrays of $2N$ elements.

If the mutual impedances between the elements are small but not zero, the above formula is still a good approximation to the gain reduction that can be expected.

COMPARISON OF THE BEAM WIDTH OF A UNIFORM ARRAY AND THE TCHEBYSCHEFF DISTRIBUTION

If all the I_k's are equal, then it is easily shown that (4) can be written (for an array of $2N$ elements) as

$$F(u) = \frac{1}{2}\,\frac{\sin 2Nu}{\sin u} = \sum_{k=0}^{N-1} \cos (2k-1)u.$$

The first null of this is therefore given by

$$\sin 2Nu = 0, \quad \text{or} \quad u = \pi/2N.$$

The corresponding first null for a Tchebyscheff distribution is given by

$$u = \text{arc cos} \left\{ \frac{1}{z_0} \cos \frac{\pi}{2(2N-1)} \right\}$$

so that, as in the general case, z_0 can be chosen so as to make the first null either equal to that of the uniform case or smaller than that.

A moment's reflection therefore shows that, when the side-lobe level starts to approach that of the uniform case, inversions must necessarily appear in the Tchebyscheff distribution. This explains the fact that the curves in Appendix IV sometimes cross.

RECTANGULAR ARRAYS

For the purpose of the ensuing discussion it is convenient to locate a co-ordinate system at the center 0 of the outer rectangle enclosing the array. Let the x, y axes of this co-ordinate system be parallel to the sides of the rectangle. Let the *constant* spacing between the elements in the x, y directions be (a), (b), respectively. Assume that there is a radiating element at 0. With these conventions, the various radiating elements will be located at points (pa, qb) where p, q take on positive and negative integral values including zero. In the general case, these radiating elements can be fed with currents possessing arbitrary amplitudes and phase with respect to the element at 0. However, if the distribution of currents in any column, row is proportional to that of any other column, row respectively, then the 2-dimensional array factor S_{xy} is the product of two 1-dimensional array factors S_x and S_y. Here S_x may be taken for convenience as the array factor arising from the distribution of currents in the radiating elements along the x axis. Similarly, S_y may be thought of as arising from the distribution of currents in the radiating elements along the y axis.

If the angles are as in Fig. 6, and if α_p, β_q represent any phase shift which may be introduced in radiating elements located at $(pa, 0)$ and $(0, qb)$, respectively, then the 2-dimensional array factor S_{xy} for a rectangular array possessing $2M+1$ elements parallel to the x axis and $(2N+1)$ elements parallel to the y axis is given by

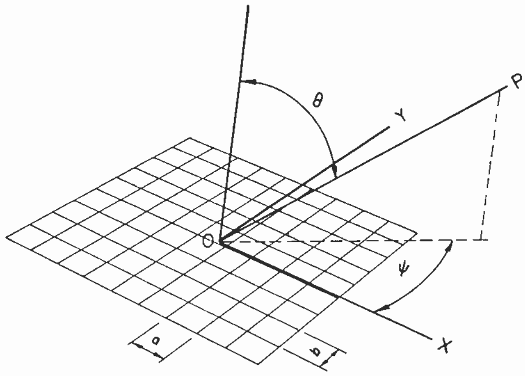

Fig. 6—Reference system for a two-dimensional array of point sources.

$$S_{xy} = \left| \left\{ \sum_{p=-M}^{M} A_p \exp \left[jp \frac{2\pi}{\lambda} a \sin\theta \cos\psi + j\alpha_p \right] \right\} \cdot \left\{ \sum_{q=-N}^{N} B_q \exp \left[jq \frac{2\pi}{\lambda} b \sin\theta \sin\psi + j\beta_q \right] \right\} \right|. \quad (35)$$

In order to apply the above 1-dimensional theory to either S_x or S_y, the factors of S_{xy}, it is merely necessary to set all the α_p's, β_q's, respectively, equal to zero and to impose the conditions that

$$A_p = A_{(-p)}; \qquad \psi = 0$$

or that

$$B_q = B_{(-q)}; \qquad \psi = \pi/2.$$

If this is done in the case of S_x, as would be convenient if a sharp azimuth pattern were desired, it would become

$$S_x = \left| A_0 + 2 \sum_{p=1}^{M} A_p \cos \left(2p \frac{\pi}{\lambda} a \sin\theta \right) \right|.$$

Letting $v = (\pi/\lambda)a \sin\theta$, this last equation becomes

$$S_x = \left| A_0 + 2 \sum_{p=1}^{M} A_p \cos (2pv) \right|. \quad (36)$$

Equation (36) is recognized as being in the same form as (5) and therefore the same design procedure applicable there should be used here. If a sharp vertical pattern is desired, S_y can be treated in a similar fashion. On the other hand, if a different type of pattern is desired, the usual techniques can be applied to determine the appropriate values of B_q.

In either event, the pattern will be given by (35). The actual current to be fed into the element located at

(pa, qb) is of course $A_pB_qe^{j(\alpha_p+\beta_q)}$ in all cases.

It is unfortunate, perhaps, that the design curves contained in the appendix were not computed for (36) and hence cannot be used to sharpen the pattern in one or both directions. However, if the column and the row of radiators passing through the center 0 is struck out, as well as every other column and row, then the resulting expressions are just those computed in the appendix. Explicitly, if

$$A_0 = 0 \qquad B_0 = 0$$

$$A_{2p} = 0 \qquad B_{2q} = 0 \qquad \begin{aligned} p &= 1, 2, \cdots, M \\ q &= 1, 2, \cdots, N \end{aligned}$$

then the separation between the elements along the x, y directions is, respectively, $(2a)$ and $(2b)$. Let these be denoted by (d) and (d'), respectively. Then if

$$w = \frac{\pi d}{\lambda} \sin \theta$$

and it is desired to apply the theory to the x direction, so that $\alpha_p = 0$, equation (36) becomes

$$\frac{S_x}{2} = \left| \sum_{p=1}^{M} A_p \cos (2p - 1) w \right|.$$

This is recognized as of the same form as (4) so that the curves contained in the appendixes are applicable. S_y can be treated similarly or again made to conform with any other desired distribution.

Experimental Verification

The preceding theory has been utilized in the design of several linear arrays with excellent results.

Specifically, 12- and 24-element arrays of directive elements with $(4/5\lambda)$ spacing at the mid-band frequency have been successfully built and made to operate over a ±10 per cent band with a 26-decibel side-lobe level. Both of the arrays were designed for a side-lobe level of 32 decibels and at the high end of the frequency band the 12-element array actually possessed a side-lobe level of 31 decibels. The performance of the 24-element array, while excellent, did not show as close an agreement with the predicted performance because of its greater complexity.

The beam widths to the half-power points were of the order of 6 degrees and 3 degrees, respectively, at the mid-band frequency and showed a total variation of about 1 degree over the band.

This experience, while admittedly limited, is sufficient to indicate that the above theory can be used successfully as a basis for design provided that a safety factor of from 3 to 5 decibels is allowed in the side-lobe level. This discrepancy between theory and practice is partly due to constructional difficulties and partly due to the finite size of the reflector behind the point sources in a physical array.

Appendix I

The nonnormalized Tchebyscheff polynomials

$$\cos (2n - 1)\theta, \quad n = 1, 2, \cdots, 10$$

$$\cos \theta = x$$

$$\cos 3\theta = x\{4x^2 - 3\}$$

$$\cos 5\theta = x\{16x^4 - 20x^2 + 5\}$$

$$\cos 7\theta = x\{64x^6 - 112x^4 + 56x^2 - 7\}$$

$$\cos 9\theta = x\{256x^8 - 576x^6 + 432x^4 - 120x^2 + 9\}$$

$$\begin{aligned} \cos 11\theta = x\{&1024x^{10} - 2816x^8 + 2816x^6 \\ &- 1232x^4 + 220x^2 - 11\}. \end{aligned}$$

$$\begin{aligned} \cos 13\theta = x\{&4096x^{12} - 13{,}312x^{10} + 16{,}640x^8 \\ &- 9984x^6 + 2912x^4 - 364x^2 + 13\} \end{aligned}$$

$$\begin{aligned} \cos 15\theta = x\{&16{,}384x^{14} - 61{,}440x^{12} + 92{,}160x^{10} \\ &- 70{,}400x^8 + 28{,}800x^6 - 6048x^4 \\ &+ 560x^2 - 15\} \end{aligned}$$

$$\begin{aligned} \cos 17\theta = x\{&65{,}536x^{16} - 278{,}528x^{14} + 487{,}424x^{12} \\ &- 452{,}608x^{10} + 239{,}360x^8 - 71{,}808x^6 \\ &+ 11{,}424x^4 - 816x^2 + 17\} \end{aligned}$$

$$\begin{aligned} \cos 19\theta = x\{&262{,}144x^{18} - 1{,}245{,}184x^{16} + 2{,}490{,}368x^{14} \\ &- 2{,}723{,}840x^{12} + 1{,}770{,}496x^{10} - 695{,}552x^8 \\ &+ 160{,}512x^6 - 20{,}064x^4 + 1140x^2 - 19\} \end{aligned}$$

$$\begin{aligned} \cos 21\theta = x\{&1{,}048{,}576x^{20} - 5{,}505{,}024x^{18} + 12{,}386{,}304x^{16} \\ &- 15{,}597{,}568x^{14} + 12{,}042{,}240x^{12} \\ &- 5{,}870{,}592x^{10} + 1{,}793{,}792x^8 - 329{,}472x^6 \\ &+ 33{,}264x^4 - 1540x^2 + 21\} \end{aligned}$$

$$\begin{aligned} \cos 23\theta = x\{&4{,}194{,}304x^{22} - 24{,}117{,}248x^{20} + 60{,}293{,}120x^{18} \\ &- 85{,}917{,}696x^{16} + 76{,}873{,}728x^{14} \\ &- 44{,}843{,}008x^{12} + 17{,}145{,}856x^{10} \\ &- 4{,}209{,}920x^8 + 631{,}488x^6 - 52{,}624x^4 \\ &+ 2024x^2 - 23\}. \end{aligned}$$

Check:

If $x = 1$, $\cos n\theta = 1$.

Appendix II

24-Element Array

$$\begin{aligned} G_{23}(x) = x\{&4{,}194{,}304I_{12}x^{22} + (-24{,}117{,}248I_{12} \\ &+ 1{,}048{,}576I_{11})x^{20} + (60{,}293{,}120I_{12} \\ &- 5{,}505{,}024I_{11} + 262{,}144I_{10})x^{18} \\ &+ (-85{,}917{,}696I_{12} + 12{,}386{,}304I_{11} \\ &- 1{,}245{,}184I_{10} + 65{,}536I_9)x^{16} + (76{,}873{,}728I_{12} \\ &- 15{,}597{,}568I_{11} + 2{,}490{,}368I_{10} - 278{,}528I_9 \\ &+ 16{,}384I_8)x^{14} + (-44{,}843{,}008I_{12} \\ &+ 12{,}042{,}240I_{11} - 2{,}723{,}840I_{10} + 487{,}424I_9 \\ &- 61{,}440I_8 + 4096I_7)x^{12} + (17{,}145{,}856I_{12} \\ &- 5{,}870{,}592I_{11} + 1{,}770{,}496I_{10} - 452{,}608I_9 \\ &+ 92{,}160I_8 - 13{,}312I_7 + 1024I_6)x^{10} \end{aligned}$$

$$
\begin{aligned}
&+ (-\,4{,}209{,}920I_{12} + 1{,}793{,}792I_{11} - 695{,}552I_{10} \\
&+ 239{,}360I_9 - 70{,}400I_8 + 16{,}640I_7 - 2816I_6 \\
&+ 256I_5)x^8 + (631{,}488I_{12} - 329{,}472I_{11} \\
&+ 160{,}512I_{10} - 71{,}808I_9 + 28{,}800I_8 - 9984I_7 \\
&+ 2816I_6 - 576I_5 + 64I_4)x^6 + (-\,52{,}624I_{12} \\
&+ 33{,}264I_{11} - 20{,}064I_{10} + 11{,}424I_9 - 6048I_8 \\
&+ 2912I_7 - 1232I_6 + 432I_5 - 112I_4 + 16I_3)x^4 \\
&+ (2024I_{12} - 1540I_{11} + 1140I_{10} - 816I_9 \\
&+ 560I_8 - 364I_7 + 220I_6 - 120I_5 + 56I_4 \\
&- 20I_3 + 4I_2)x^2 + (-\,23I_{12} + 21I_{11} - 19I_{10} \\
&+ 17I_9 - 15I_8 + 13I_7 - 11I_6 + 9I_5 - 7I_4 \\
&+ 5I_3 - 3I_2 + I_1)\}.
\end{aligned}
$$

Check:

$$
\begin{aligned}
G_{23}(1) = {}& I_1 + I_2 + I_3 + I_4 + I_5 + I_6 + I_7 + I_8 + I_9 \\
&+ I_{10} + I_{11} + I_{12}.
\end{aligned}
$$

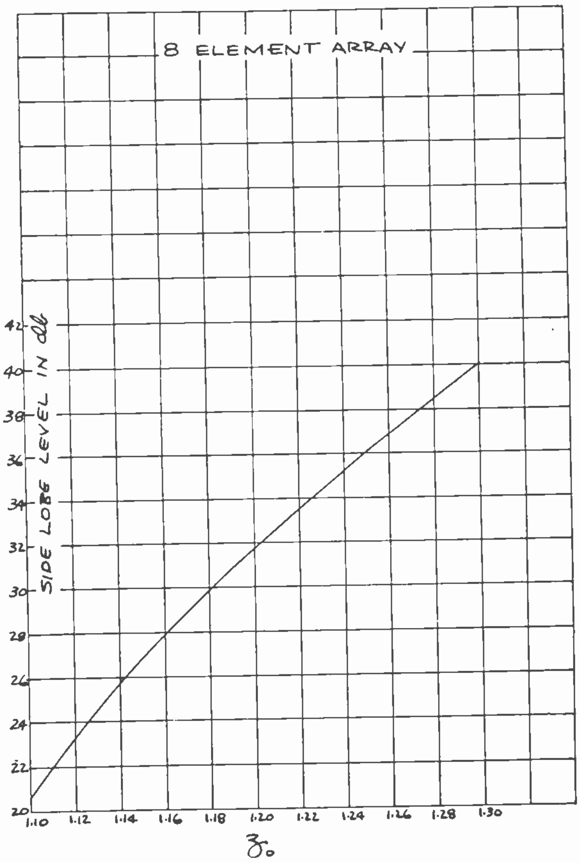

Fig. 7—The side-lobe level in decibels for "the optimum current distribution" as a function of the scale-contraction factor z_0 for an 8-element array.

Appendix III

Design Equations for

12-Element Array

$I_6 = z_0^{11}$

$I_5 = 11(I_6 - z_0^9)$

$I_4 = 9I_5 - 44I_6 + 44z_0^7$

$I_3 = 7I_4 - 27I_5 + 77I_6 - 77z_0^5$

$I_2 = 5I_3 - 14I_4 + 30I_5 - 55I_6 + 55z_0^3$

$I_1 = 3I_2 - 5I_3 + 7I_4 - 9I_5 + 11I_6 - 11z_0$

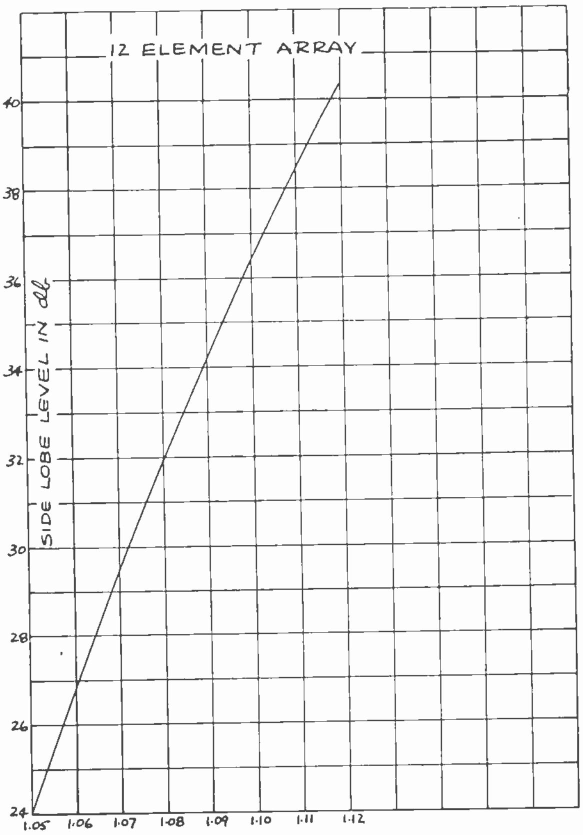

Fig. 8—The side-lobe level in decibels for "the optimum current distribution" as a function of the scale-contraction factor z_0 for a 12-element array.

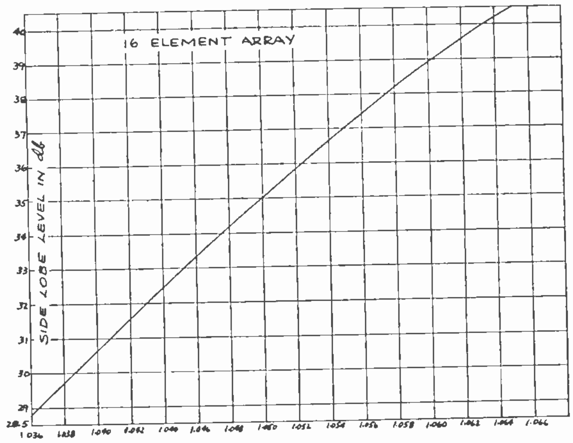

Fig. 9—The side-lobe level in decibels for "the optimum current distribution" as a function of the scale-contraction factor z_0 for a 16-element array.

16-Element Array

$I_8 = z_0^{15}$

$I_7 = 15I_8 - 15z_0^{13}$

$I_6 = 13I_7 - 90I_8 + 90z_0^{11}$

$I_5 = 11I_6 - 65I_7 + 275I_8 - 275z_0^9$

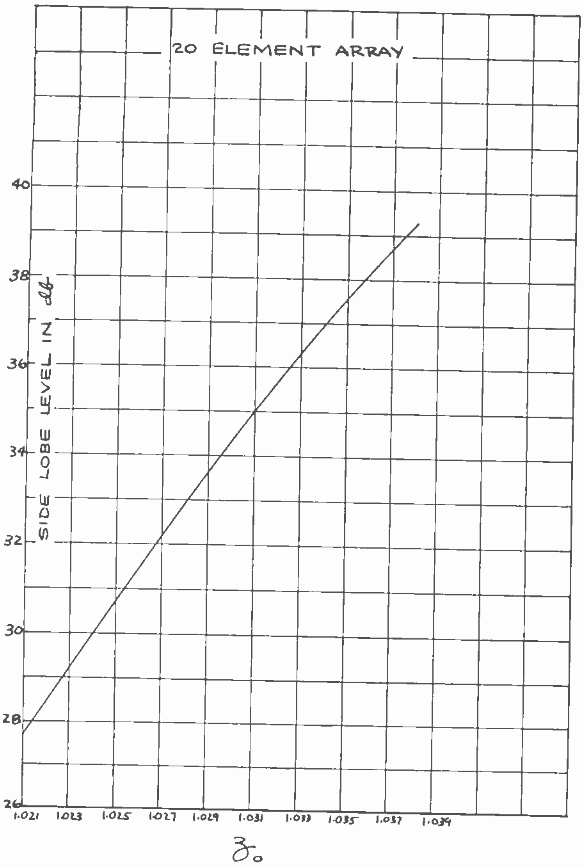

Fig. 10—The side-lobe level in decibels for "the optimum current distribution" as a function of the scale-contraction factor z_0 for a 20-element array.

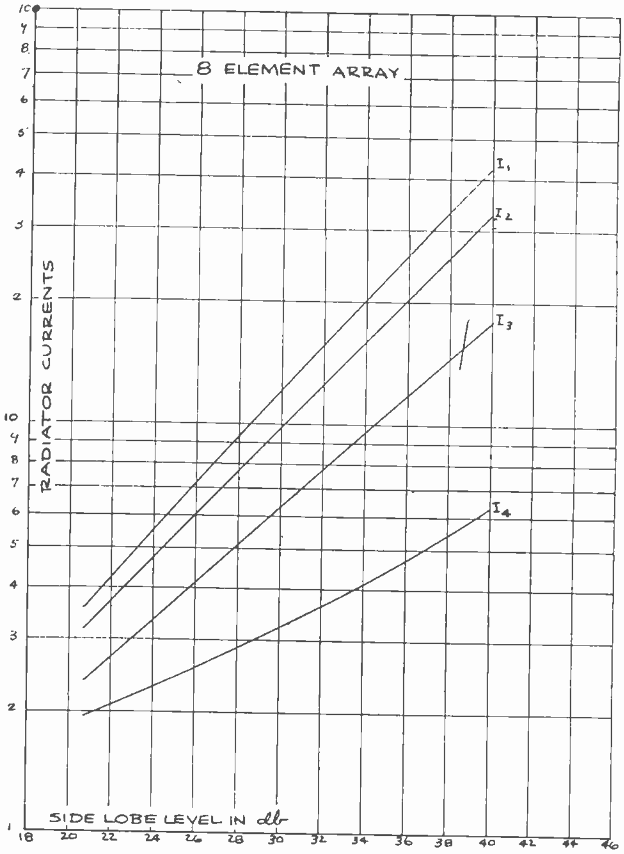

Fig. 12—The *relative* current values for an 8-element array necessary for "the optimum current distribution" as a function of side-lobe level in decibels.

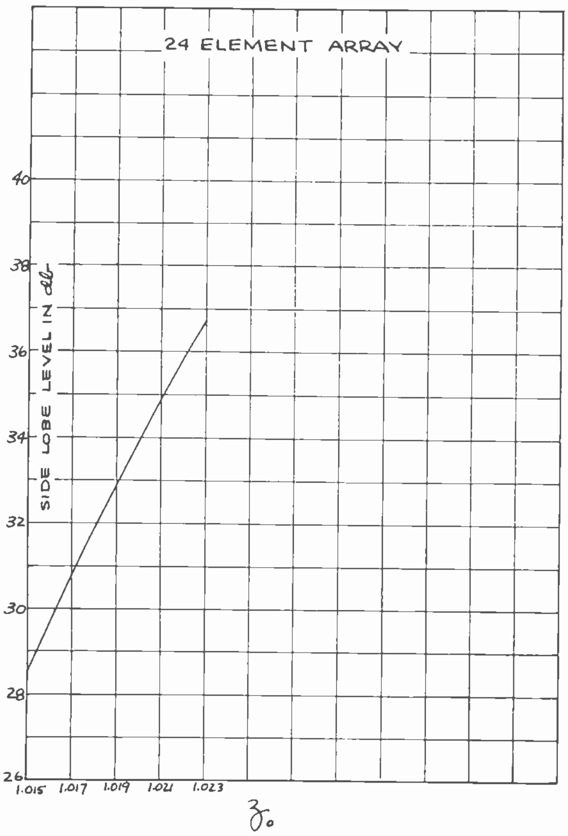

Fig. 11—The side-lobe level in decibels for "the optimum current distribution" as a function of the scale-contraction factor z_0 for a 24-element array.

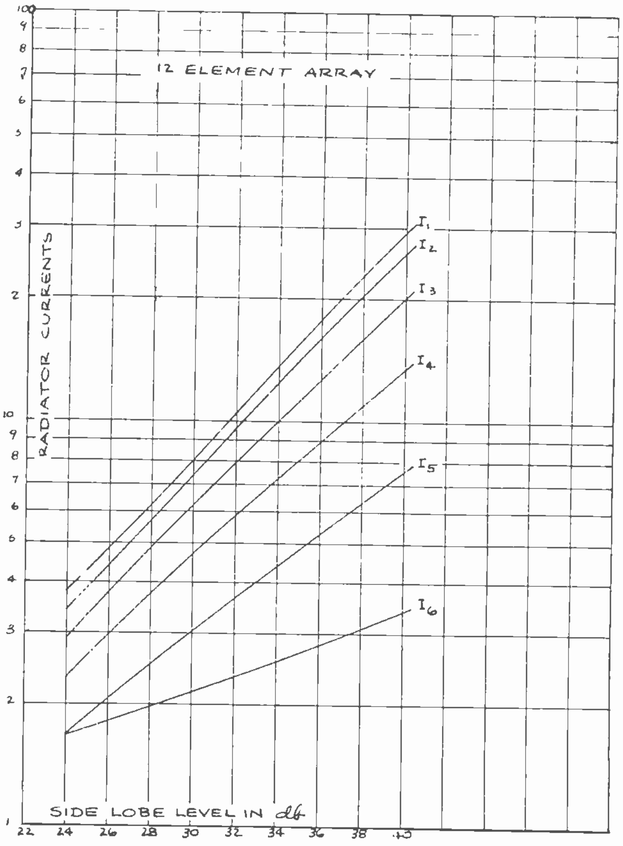

Fig. 13—The *relative* current values for a 12-element array necessary for "the optimum current distribution" as a function of side-lobe level in decibels.

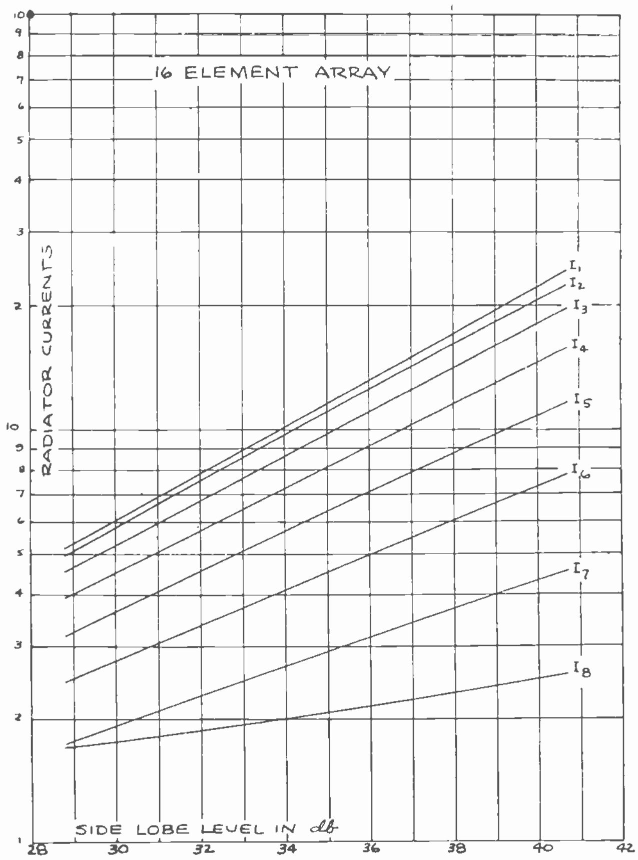

Fig. 14—The *relative* current values for a 16-element array necessary for "the optimum current distribution" as a function of side-lobe level in decibels.

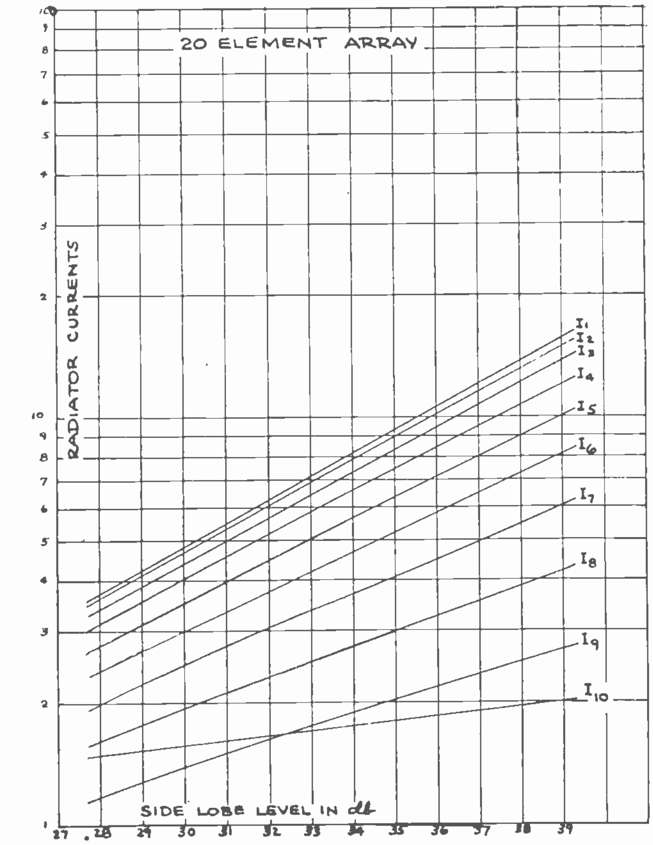

Fig. 15—The *relative* current values for a 20-element array necessary for "the optimum current distribution" as a function of side-lobe level in decibels.

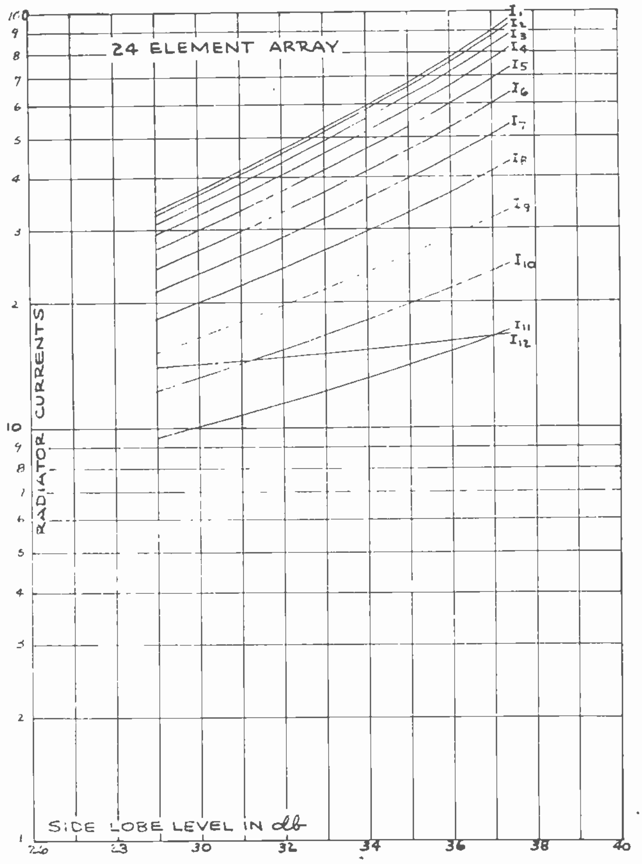

Fig. 16—The *relative* current values for a 24-element array necessary for "the optimum current distribution" as a function of side-lobe level in decibels.

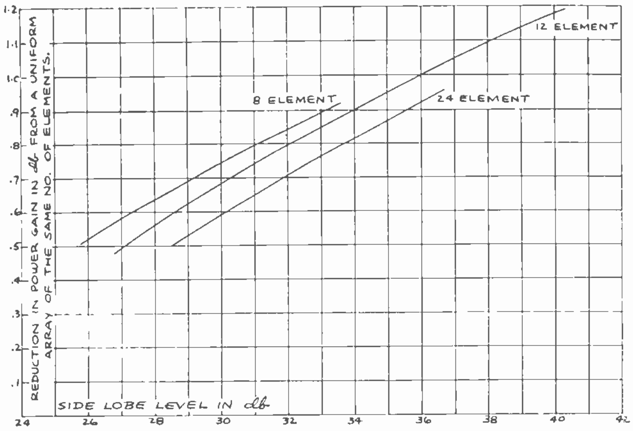

Fig. 17—The power-gain reduction of "the optimum current distribution" with respect to a "uniform" array of the same number of elements as a function of side-lobe level in decibels for 8-, 12-, and 24-element arrays, under the assumption that mutual impedances between the radiators are negligible.

$$I_4 = 9I_5 - 44I_6 + 156I_7 - 450I_8 + 450z_0^7$$

$$I_3 = 7I_4 - 27I_5 + 77I_6 - 182I_7 + 378I_8 - 378z_0^5$$

$$I_2 = 5I_3 - 14I_4 + 30I_5 - 55I_6 + 91I_7 - 140I_8 + 140z_0^3$$

$$I_1 = 3I_2 - 5I_3 + 7I_4 - 9I_5 + 11I_6 - 13I_7 + 15I_8 - 15z_0.$$

20-ELEMENT ARRAY

$$I_{10} = z_0^{19}$$

$$I_9 = 19I_{10} - 19z_0^{17}$$

$$I_8 = 17I_9 - 152I_{10} + 152z_0^{15}$$

$$I_7 = 15I_8 - 119I_9 + 665I_{10} - 665z_0^{13}$$

$$I_6 = 13I_7 - 90I_8 + 442I_9 - 1729I_{10} + 1729z_0^{11}$$

$$I_5 = 11I_6 - 65I_7 + 275I_8 - 935I_9 + 2717I_{10} - 2717z_0^9$$

$$I_4 = 9I_5 - 44I_6 + 156I_7 - 450I_8 + 1121I_9 - 2508I_{10} + 2508z_0^7$$

$$I_3 = 7I_4 - 27I_5 + 77I_6 - 182I_7 + 378I_8 - 714I_9 + 1254I_{10} - 1254z_0^5$$

$$I_2 = 5I_3 - 14I_4 + 30I_5 - 55I_6 + 91I_7 - 140I_8 + 204I_9 - 285I_{10} + 285z_0^3$$

$$I_1 = 3I_2 - 5I_3 + 7I_4 - 9I_5 + 11I_6 - 13I_7 + 15I_8 - 17I_9 + 19I_{10} - 19z_0.$$

24-ELEMENT ARRAY

$$I_{12} = z_0^{23}$$

$$I_{11} = 23I_{12} - 23z_0^{21}$$

$$I_{10} = 21I_{11} - 230I_{12} + 230z_0^{19}$$

$$I_9 = 19I_{10} - 189I_{11} + 1311I_{12} - 1311z_0^{17}$$

$$I_8 = 17I_9 - 152I_{10} + 952I_{11} - 4692I_{12} + 4692z_0^{14}$$

$$I_7 = 15I_8 - 119I_9 + 665I_{10} - 2940I_{11} + 10{,}948I_{12} - 10{,}948z_0^{13}$$

$$I_6 = 13I_7 - 90I_8 + 442I_9 - 1729I_{10} + 5733I_{11} - 16{,}744I_{12} + 16{,}744z_0^{11}$$

$$I_5 = 11I_6 - 65I_7 + 275I_8 - 935I_9 + 2717I_{10} - 7007I_{11} + 16{,}445I_{12} - 16{,}445z_0^9$$

$$I_4 = 9I_5 - 44I_6 + 156I_7 - 450I_8 + 1122I_9 - 2508I_{10} + 5148I_{11} - 9867I_{12} + 9867z_0^7$$

$$I_3 = 7I_4 - 27I_5 + 77I_6 - 182I_7 + 378I_8 - 714I_9 + 1254I_{10} - 2079I_{11} + 3289I_{12} - 3289z_0^5$$

$$I_2 = 5I_3 - 14I_4 + 30I_5 - 55I_6 + 91I_7 - 140I_8 + 204I_9 - 285I_{10} + 385I_{11} - 506I_{12} + 506z_0^3$$

$$I_1 = 3I_2 - 5I_3 + 7I_4 - 9I_5 + 11I_6 - 13I_7 + 15I_8 - 17I_9 + 19I_{10} - 21I_{11} + 23I_{12} - 23z_0.$$

APPENDIX IV

The accompanying design curves are shown for broadside, symmetric arrays of 8, 12, 16, 20, and 24 elements over an approximate side-lobe-level range of 26 to 40 decibels.

Figs. 7, 8, 9, 10, and 11 are useful in estimating beam widths to half-power points.

Figs. 12, 13, 14, 15, and 16 give the *relative* current values needed in design.

Fig. 17 is useful in predicting power-gain performance.

High-Impedance Cable*

HEINZ E. KALLMANN†, SENIOR MEMBER, I.R.E.

***Summary*—A cable with an impedance of the order of 1000 ohms is described. It resembles the usual flexible concentric cable with a 3/8-inch outside diameter, but its inner conductor is a single-layer coil continuously wound on a flexible core of 0.110-inch diameter. The cable is suitable for video connections from chassis to chassis and to remote indicators.**

PRESENT types of video amplifiers are built with load impedances of the order of 1000 ohms; the cables, however, now used for video signals have impedances of 50 to 100 ohms, with capacitances of 30 to 100 micromicrofarads per meter. They may be matched to correspondingly low load resistances, or they may be treated as lumped load capacitances, in either case enforcing low gain and low peak-voltage output available from a given tube.

To avoid these losses, cables having much higher surge impedances are desirable. A suitable design can be derived from that used for delay lines of the distributed-parameter type, but with dimensions modified so as to yield the high impedance Z_0 with the least possible signal delay and attenuation per unit length. To this end, the inductance L per unit length is increased, while the capacitance C is kept low, since

$$Z_0 = \sqrt{L/C} \text{(ohms, henries, farads).} \qquad (1)$$

An experimental cable was made, resembling a low-capacitance concentric cable except that the inner conductor was a small-diameter single-layer coil, continuously wound on a flexible core, as shown with dimensions in Figs. 1 and 2. The core, 0.060-inch thick, was made of Saran, a moderately flexible plastic; the inner conductor was close-wound on it with No. 34 HF Formex wire. A helix wound from 0.065-inch polystyrene with 0.15-inch pitch was used as a spacer, with an outer diameter of about 0.25 inch. The outer conductor was 3/16-inch braid of 175 tinned 0.005-inch copper wires. The cable, with an outside diameter of 5/16 inch, can be bent to a 2-inch diameter circle.

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* Decimal classification: R117.2×R282.1. Original manuscript received by the Institute, January 7, 1946; revised manuscript received, February 27, 1946. This paper is based on work done for the Office of Scientific Research and Development under contract OEMsr-262 with the Radiation Laboratory, Massachusetts Institute of Technology. The cable described herein was subsequently produced by the Federal Telephone and Radio Corporation under contract OEMsr-1283.

† Formerly, Radiation Laboratory, Massachusetts Institute of Technology, Cambridge, Massachusetts; now, consulting engineer, New York, N. Y.

A few short samples were made and one continuous piece of cable 24 feet in length. Its total capacitance C was 365 micromicrofarads, and its delay T was 0.462 microseconds at low frequencies, dropping steadily to 0.459 microsecond at 22 megacycles, as shown in Fig. 3.

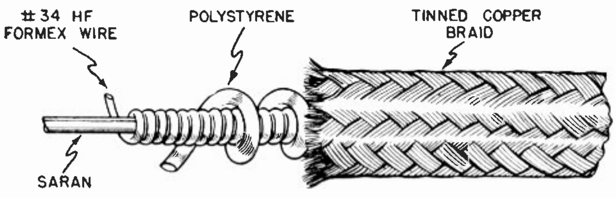

Fig. 1—Construction of experimental cable.

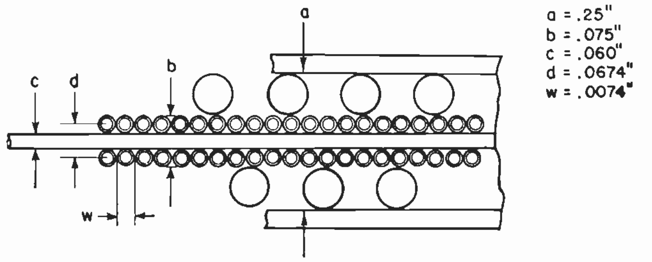

Fig. 2—Dimensions of experimental cable.

Its impedance was thus 1260 ohms, since from (1) for the impedance and from (2) for the time delay[1]

$$T = LC \text{ (seconds, henries, farads)} \qquad (2)$$

follows equation (3)

$$Z = T/Z \text{ (ohms, seconds, farads).} \qquad (3)$$

The direct-current resistance was 200 ohms; the transmission loss was found to rise steadily from 0.7 decibel at very low frequencies to 1.7 decibels at 5 megacycles, and to 3.3 decibels at 10 megacycles, as plotted in Fig. 4. Very satisfactory transmission of short pulses confirmed expectations.

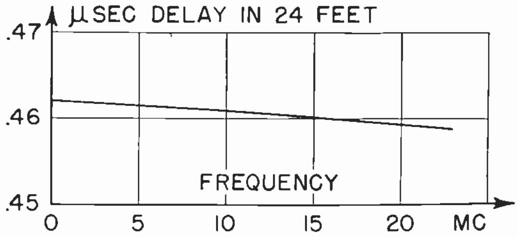

Fig. 3—Delay characteristic of experimental cable.

The type of cable shown in Fig. 5, now in production as type RG-65/U, is built more solidly, sacrificing some of the above electrical characteristics. In particular, an inner conductor wound of No. 34 American Wire Gauge has a smaller diameter than is now believed mechanically safe. Future experience will show just how fine a wire is safe; but the wire diameter is the most consequential design parameter, as will be understood from the following analysis:

Let a = inside diameter of outer conductor, in centimeters;
b = outside diameter of coil, in centimeters;
c = diameter of coil core, in centimeters;
d = diameter of coil, between wire centers, in centimeters;
k = effective dielectric constant of spacer;
n = number of coil turns per meter;
w = over-all diameter of coil wire, in centimeters;
A = transmission loss, in decibels per meter;
C = capacitance, in farads per meter;
L = inductance of coil, in henries per meter;
R = resistance of cable, ohms per meter;
T = time delay, microseconds per meter;
Z = cable impedance, ohms.

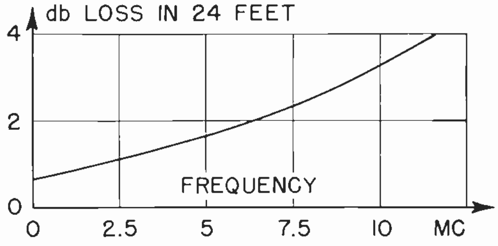

Fig. 4—Attenuation characteristic of experimental cable.

The inductance L of a continuously wound single-layer coil is given by (4)

$$L = 10^{-11}\pi^2 n^2 d^2 \text{ henries per meter.} \qquad (4)$$

The capacitance C of a concentric cable is given by

$$C = \frac{24 \times 10^{-12}\, k}{\log_{10} a/b} \text{ farads per meter.} \qquad (5)$$

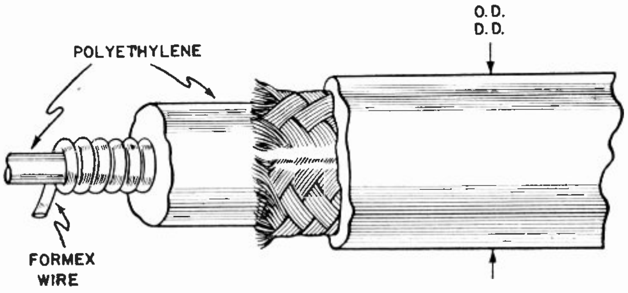

Fig. 5—Construction of manufactured cable.

From (1), (4), and (5), follows (6) for the impedance

$$Z = \sqrt{\frac{10^{-11}\pi^2 n^2 d^2 \log_{10} a/b}{24 \times 10^{-12}\, k}} = \frac{\pi n d}{\sqrt{2.4k}} \cdot \sqrt{\log_{10} a/b}. \qquad (6)$$

From (2), (4), and (5), follows (7) for the time delay

$$T = 10^6 \sqrt{\frac{24 \times 10^{-23}\pi^2 n^2 d^2 k}{\log_{10} a/b}} = \frac{10^{-5}\pi d n \sqrt{2.4k}}{\sqrt{\log_{10} a/b}} \cdot \qquad (7)$$

If, with negligible error, the surface of the coiled inner

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[1] William L. Everitt, "Communication Engineering," McGraw-Hill Book Company, New York, N. Y., 1937, chap. 4, pp. 94–128, equations (35c) and (36a).

conductor is assumed to be a cylinder of the diameter b, then

$$b = d + w \tag{8}$$

and the core diameter is, evidently,

$$c = d - w. \tag{9}$$

From (6) and (7) it follows that the impedance Z rises, and the delay T decreases, with increased outer diameter a. The design of a cable, thus, should begin with a choice of the largest practicable outer diameter. For example, in order to fit into $\frac{3}{8}$-inch fittings, the cable may have an outer diameter as large as 0.405 inch. Allowing for an average of 0.030-inch wall of a protecting jacket, and 0.016 inch for average thickness of the outer conductor, the outer diameter of the dielectric becomes 0.308 inch. The following computations are based on this and on a dielectric constant $k = 2.25$, as found for a solid packing of polyethylene. Lowering of the effective dielectric constant by insertion of a loosely wound helical spacer is contemplated, improving both the impedance and the delay proportionally to $1/\sqrt{k}$.

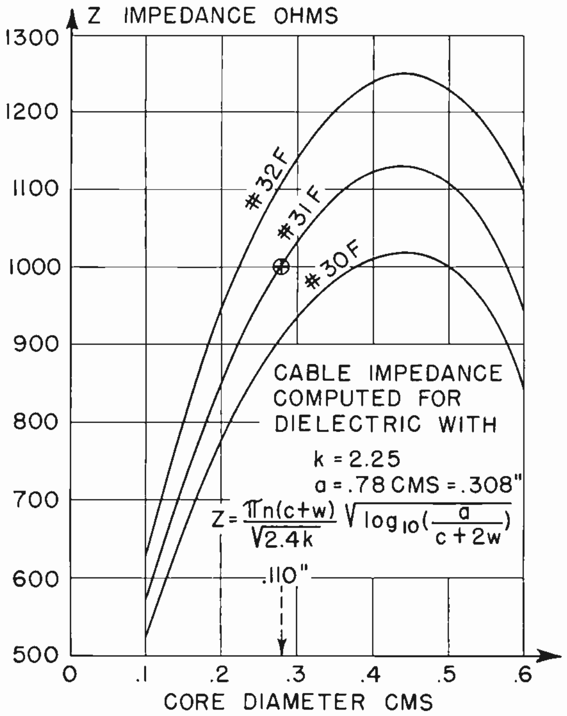

Fig. 6—Cable impedance as function of core diameter.

The impedance and the delay were computed from (6) and (7), on the basis of $a = 0.308$ inch and $k = 2.25$. They are plotted in Figs. 6 and 7, as a function of the core diameter c. Three curves are presented in each case, computed for coiled inner conductors close-wound with three different wire gauges. They are

Formex copper wire No. 30F; $w = 0.0108$ inch
No. 31F; $w = 0.0099$ inch
No. 32F; $w = 0.0089$ inch.

Fig. 6 shows that in all cases the impedance goes through a maximum, rising at first linearly with c in the numerator of (7), and then falling with $\sqrt{\log_{10} a/b}$. As can be seen, the maximum in each case is reached at approximately the same value of c; indeed, if w is negligible in comparison with d, so that $d \approx b$, then it can be shown that the maximum impedance is always reached for $a/d = \sqrt{e} = 1.65$; thus, for $a = 0.308$ inch, $d \approx 0.187$ and $c \approx 0.45$ centimeter.

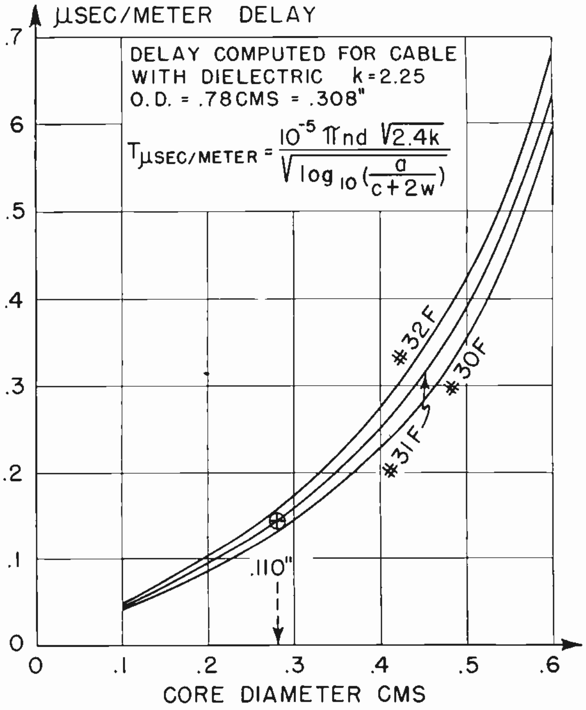

Fig. 7—Signal delay as function of core diameter.

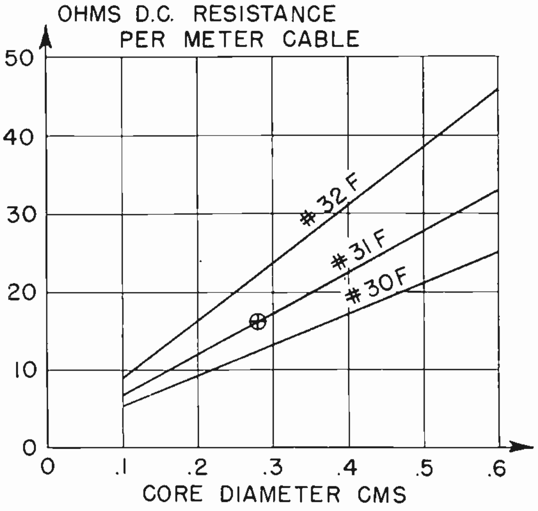

Fig. 8—Coil resistance as function of core diameter.

Judging from Fig. 6, a value of c at, or near, 0.45 centimeters would be a preferred choice yielding maximum impedance, besides maintaining it unchanged with large variations of the core diameter. However, the following other arguments militate against the choice:

1. As shown in Fig. 7, the delay per unit length of cable rises rapidly with the diameter of the core, due both to increased coil diameter (increased inductance) and to closer capacitor spacing (increased capacitance). The larger the delay, the further the spacing of echoes due to improper terminations.

2. The transmission loss[1] in the cable,

$$A_{db} = \frac{4.35R}{Z} \qquad (10)$$

is almost exclusively due to the resistance of R of the inner conductor, rising as plotted in Fig. 8 with the wire length, which in turn is proportional to the core diameter.

3. Parts of the magnetic field around the coiled inner conductor will cause eddy-current losses in the closed turn of the outer conductor, unless that conductor is either far enough away or braided of separately insulated wires.

A suitable compromise value for the core diameter, $c = 0.28$ centimeter $= 0.110$ inch, is marked in Figs. 6, 7, and 8; it yields an impedance of 89 per cent of the optimum, but the corresponding delay is reduced to 49 per cent, the wire resistance to about 65 per cent, and the outer conductor has then a safe diameter 2.8 times that of the coil. It may be noted that the value of c so determined only depends on the value of a and k, but its choice is not affected if, for example, another impedance is desired. Fig. 6 shows that, in such cases, choice of a different wire gauge, wound on the same core diameter, is the only, and the most efficient, change required. The impedance rises by over 10 per cent each time the wire gauge is made one step higher (finer wire); the delay rises in the same proportion, but the series resistance R rises by almost 35 per cent, and with it the transmission loss by about 20 per cent. At present, choice of American Wire Gauge No. 32 is thought to be a wise compromise, yielding 1000 ohms impedance with safe mechanical strength.

A cable based on this design is manufactured by the Federal Telegraph and Radio Corporation in Newark, New Jersey, as type RG-65/U. Its specifications are as follows:

Flexible plastic core, 0.110 inch ±0.010 inch diameter.
Close-wound inner conductor, No. 32 F Formax.
Spacer of solid polyethylene extruded on this to an outer diameter, 0.285 inch ±0.010 inch.
Outer conductor braided of bare copper wire, American Wire Gauge No. 33.
Jacket of vinylite, 0.030 inch.
Over-all diameter, 0.405 inch ±0.010 inch.

Its electrical data are:

Impedance $Z = 950 \pm 50$ ohms.
Capacitance $C = 42$ micromicrofarads per foot.
Direct-current resistance = 7 ohms per foot.
Attenuation
    5.5 decibels per 100 feet at 1 megacycle.
    10.2 decibels per 100 feet at 3 megacycles.
    21.5 decibels per 100 feet at 10 megacycles.
    40 decibels per 100 feet at 30 megacycles.

Delay $T = 0.042$ microsecond per foot at 5 megacycles.

A Study of Locking Phenomena in Oscillators*

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***Summary*—Impression of an external signal upon an oscillator of similar fundamental frequency affects both the instantaneous amplitude and instantaneous frequency. Using the assumption that time constants in the oscillator circuit are small compared to the length of one beat cycle, a differential equation is derived which gives the oscillator phase as a function of time. With the aid of this equation, the transient process of "pull-in" as well as the production of a distorted beat note are described in detail.**

It is shown that the same equation serves to describe the motion of a pendulum suspended in a viscous fluid inside a rotating container. The whole range of locking phenomena is illustrated with the aid of this simple mechanical model.

I. INTRODUCTION

THE BEHAVIOR of a regenerative oscillator under the influence of an external signal has been treated by a number of authors. The case of synchronization by the external signal is of great practical interest; it has been applied to frequency-modulation receivers[1,2] and carrier-communication systems,[3] and formulas, as well as experimental data, have been given for the conditions required for synchronization.[4–8] The other case, arising when the external signal is not strong enough to effect synchronization, is of practical importance in beat-frequency oscillators. Here the tendency toward synchronization lowers the beat frequency and produces strong harmonic distortion of the beat note.[4–8]

It is the purpose of this paper to derive the rate of phase rotation of the oscillator voltage at a given instant from the phase and amplitude relations between the oscillator voltage and the external signal at that

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† Zenith Radio Corporation, Chicago, Illinois.

[1] C. W. Carnahan and H. P. Kalmus, "Synchronized oscillators as frequency-modulation receiver limiters," *Electronics*, vol. 17, pp. 108–112; August, 1944.

[2] G. L. Beers, "A frequency-dividing locked-in oscillator frequency-modulation receiver," PROC. I.R.E., vol. 32, pp. 730–738; *Elec. Eng.* December, 1944.

[3] D. G. Tucker, "Carrier frequency synchronization," *Post Office Elec. Eng.*, vol. 33, pp. 75–81; July, 1940.

[4] E. V. Appleton, "The automatic synchronization of triode oscillators," *Proc. Camb. Soc.*, vol. 21, pp. 231–248; 1922–1923.

[5] D. G. Tucker, "The synchronization of oscillators," *Elec. Eng.*, vol. 15, pp. 412–418, March, 1943; pp. 457–461, April, 1943; vol. 16, pp. 26–30; June, 1943.

[6] D. G. Tucker, "Forced oscillations in oscillator circuits," *Jour. I.E.E.* (London), vol. 92, pp. 226–234; September, 1945.

[7] S. Byard and W. H. Eccles, "The locked-in oscillator," *Wireless Eng.*, vol. 18, pp. 2–6; January, 1941.

[8] H. G. Möller, "Über Störungsfreien Gleichstromempfang mit den Schwingaudion," *Jahr. für Draht. Teleg.*, vol. 17, pp. 256–287; April, 1921.

instant; in other words, to find a differential equation for the oscillator phase as a function of time. This equation must be expected to describe the case of synchronization where any transient disturbance vanishes in time, giving way to a steady state in which phase difference between oscillator and external signal is constant. It must also give frequency and wave form of the beat note, in case no synchronization occurs. To cover both cases, it must contain a parameter which decides whether or not the transient term will vanish in time, thus producing an equivalent to the criteria for synchronization derived by other methods. Finally, the equation must suggest a mechanical analogy simple enough to give a clear picture of what actually happens in an oscillator when an external signal is impressed upon it.

In the following analysis, it is assumed that the impressed signal and the free oscillation are of similar frequency. Locking effects at submultiple frequencies are analogous in many respects, but the analysis does not apply directly.

II. CONDITIONS FOR BANDWIDTH AND TIME CONSTANTS

In attempting to derive the rate of phase rotation at a given instant from no other data but phase and amplitude relations at that same instant, we assume implicitly that there are no aftereffects from different conditions which may have existed in the past. The value of such an assumption lies in the fairly simple analysis which it permits. But our experience with practical oscillators warns us that it may not always be justified. In this section we will study the requirements which an oscillator must meet so that our analysis may be applicable.

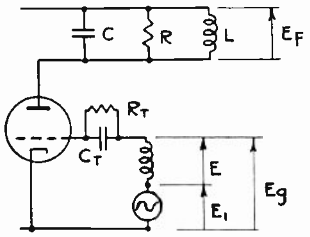

Fig. 1—Oscillator circuit.

If an oscillator is disturbed but not locked by an external signal, we observe a beat note—periodic variations of frequency and amplitude. If these variations are rapid, a sharply tuned circuit in the oscillator may not be able to respond instantaneously, or a capacitor may delay the automatic readjustment of a bias voltage. In either case, our assumption would be invalid. To validate it, we shall have to specify a minimum bandwidth for the tuned circuit and a maximum time constant for the biasing system. To establish these limits, let us study the circuit shown in Fig. 1, with the understanding that the impressed signal is not strong enough to cause locking. We will use the following symbols:

Angular frequencies:
ω_0 = free-running frequency
ω_1 = frequency of impressed signal
$\Delta\omega_0 = \omega_0 - \omega_1$ = "undisturbed" beat frequency
ω = instantaneous frequency of oscillation
$\Delta\omega = \omega - \omega_1$ = instantaneous beat frequency.

Voltages:
E_p = voltage across plate load
E = voltage induced in grid coil
E_1 = voltage of impressed signal
E_g = resultant grid voltage
Q = figure of merit of plate load L, C, R.

If the oscillator were undisturbed, the only frequencies present[9] would be ω_0 and ω_1, producing a beat frequency $\Delta\omega_0$. Actually, a lower beat frequency is observed, so that the value of ω averaged over one complete beat cycle is shifted toward ω_1. We cannot yet predict, however, how large the excursions of the momentary value of ω might be. We may think of ω as of a signal which is frequency modulated with the beat note $\Delta\omega$; this beat note is known to contain strong harmonics if the oscillator is almost locked, so that ω can be represented by a wide spectrum of frequencies extending to both sides of its average value.

If the plate circuit is to reproduce variations of ω without noticeable delay, each half of the pass band must be wide compared to the "undisturbed" beat frequency. For a single tuned circuit we can write

$$\frac{\omega_0}{2Q} \gg \Delta\omega_0. \tag{1}$$

Without reference to any specific type of circuit, we can say that the frequency of the external signal should be near the center of the pass band.

Up to this point, we have assumed that the circuit of Fig. 1 operates as a linear amplifier. But it is well known[10] that some nonlinear element must be present to stabilize the amplitude of any self-excited oscillator. Curved tube characteristics may produce a nonlinear relation between grid voltage and plate current, distorting every individual cycle of oscillation ("instantaneous" nonlinearity); plate-current saturation is an example for this case. On the other hand, a nonlinear element may control the transconductance as the amplitude varies, thus acting like an automatic volume control; the relation between grid voltage and plate current may then remain linear over a period of many cycles. Oscillators stabilized by an inverse-feedback circuit containing an incandescent lamp provide perhaps the best example for this type. The combination of C_T and R_T in the circuit of Fig. 1 functions also as a controlling element of the automatic-volume-control type; at the same time, some nonlinearity of the "instantaneous" type will generally be present in this circuit.

We want the instantaneous amplitudes of the plate

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[9] "Frequency" always means the angular frequency.

[10] B. van der Pol, "The nonlinear theory of electric oscillations," PROC. I.R.E., vol. 22, pp. 1051–1086; September, 1934.

current and of the voltage E fed back to the grid to be the same as if the total grid voltage E_r at that instant had been stationary for some time; earlier amplitudes should have no noticeable aftereffects. How fast the amplitudes vary depends on the beat frequency. The amplitude control mechanism should, therefore, have a time constant which is short compared to one beat cycle.[11] (For the circuit of Fig. 1 this time constant would be of the order $T = C_T R_T$.) Since the shortest possible beat cycle corresponds to the "undisturbed" beat frequency $\Delta\omega_0$, we can write

$$T \ll \frac{1}{\Delta\omega_0} \cdot \qquad (2)$$

If the oscillator contains only amplitude limiting of the "instantaneous" type, this condition is inherently satisfied. An oscillator of the pure automatic-volume-control type will show the same locking and synchronizing effects as long as it fulfills[12] condition (2). But when the amplitude control mechanism acts too slow to accommodate the beat frequency, phenomena of an entirely different character appear. Such an oscillator would fall outside the scope of the mathematical analysis presented in the following, but its special characteristics merit brief discussion.

In an oscillator of the pure automatic-volume-control type, let us represent all elements outside the tuned circuit L, C, R by a negative admittance connected in parallel with L, C, R. The numerical value of this negative admittance is proportional to the gain in the oscillator tube. Over a long period of time, the automatic-volume-control mechanism will so adjust the gain that the negative admittance becomes numerically equal to the positive loss admittance of L, C, R. At this point the net loss vanishes and the prevailing amplitude is maintained indefinitely, as if the tuned circuit had infinite Q.

Now, let an external signal of slightly different frequency be superimposed upon this oscillation, so that the resulting amplitude varies periodically. Then if the automatic-volume-control mechanism acts so slowly that no substantial gain adjustments can be made within one beat cycle, that value of negative admittance which resulted in zero net loss will be retained. In other words, the system acts as if the Q of the plate circuit were still infinitely large. An external signal E_1 with a frequency very close to ω_0 will then produce a large near-resonant amplitude, increasing further the closer ω_1 approaches ω_0. This magnified signal of frequency ω_1, superimposed on the original signal of frequency ω_0, which is still maintained, produces amplitude modulation of a percentage much greater than would correspond to the ratio E_1/E.

Evidently, similar effects could be observed if the tuned circuit had of itself a Q high enough to violate condition (1). This suggests an alternative way of stating that condition. The tuned circuit will "memorize" phase and amplitude for a period of the order T', its "decay time." This period must be short compared to a beat cycle[11]

$$T' \ll \frac{1}{\Delta\omega_0} \cdot \qquad (1a)$$

For a simple tuned circuit, $T' = (2Q/\omega_0)$ hence $(\omega_0/2Q) \gg \Delta\omega_0$ which is the same as (1).

If an oscillator fulfills both conditions (1) and (2), the amplitude modulation arising from a given signal E_1 is solely determined by the ratio E_1/E and by the shape of the amplitude-limiting or automatic-volume-control characteristic. Most oscillators operate in a fairly flat part of this characteristic, so that the amplitude actually varies less than in proportion to E_1/E. Keeping this in mind, we further assume a weak external signal

$$E_1 \ll E \qquad (3)$$

so that the amplitude variations of E will also be small compared to E itself.

A surprisingly large number of practical cases meet all three conditions.

III. DERIVATION OF THE PHASE AS A FUNCTION OF TIME

Let Fig. 2 be a vector representation of the voltages in the grid circuit as they are found at a given instant.

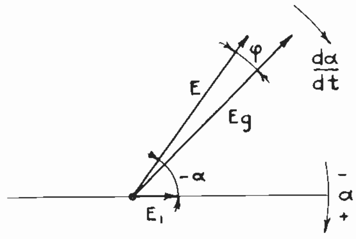

Fig. 2—Vector diagram of instantaneous voltages.

Furthermore, let E_1 be at rest with respect to our eyes; any vector at rest will therefore symbolize an angular frequency ω_1, that of the external signal, and a vector rotating clockwise with an angular velocity $(d\alpha/dt)$ shall represent an angular frequency $\omega_1 + (d\alpha/dt)$, or angular beat frequency of

$$\Delta\omega = \frac{d\alpha}{dt} \qquad (4)$$

relative to the external signal.

It is important to keep in mind that this vector diagram shows beat frequency and phase. Many high-frequency oscillations may occur during a small shift of the vectors. We call $(d\alpha/dt)$ the instantaneous angular beat frequency; we would count $(1/2\pi)(d\alpha/dt)$ beats per second if this speed of rotation were maintained. Actually, $(d\alpha/dt)$ may vary and a complete beat cycle may never be accomplished.

With no external signal impressed, E_g and E must coincide: the voltage E returned through the feedback

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[11] $1/\Delta w_0$, or the time required for one radian of a beat cycle, is used in the following.

[12] For synchronization on a subharmonic of the impressed signal, nonlinearity of the "instantaneous" type is necessary.

circuit must have the same amplitude and phase as the voltage E_g applied to the grid. Those nonlinear elements which limit the oscillator amplitude will adjust the gain so that $|E| = |E_g|$; but the phase can only coincide at one frequency, the free-running frequency ω_0. At any other frequency the plate load would introduce phase shift between E_g and E. Fig. 3 shows a typical curve of phase shift versus frequency for a single tuned circuit as assumed in Fig. 1. The amount of lead or lag of the voltage drop across such a circuit with respect to the current flowing through it is plotted. For our oscillator circuit, we may take the curve to represent the lead or lag of E with respect to E_g as a function of frequency.

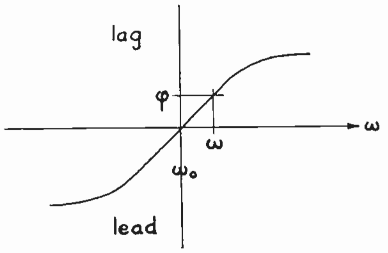

Fig. 3—Phase versus frequency for a simple tuned circuit.

Let now an external voltage E_1 be introduced, and let Fig. 2 represent the voltage vectors at a given instant during the beat cycle. Evidently, the voltage E returned through the feedback circuit is now no longer in phase with the grid voltage E_g; the diagram shows E lagging behind E_g by a phase angle ϕ.

No such lag could be produced if the oscillator were still operating at its free frequency ω_0. We conclude that the frequency at this instant exceeds ω_0 by an amount which will produce a lag equal to ϕ in the plate circuit.

With $E_1 \ll E$ according to our third condition, inspection of Fig. 2 yields

$$\phi = \frac{E_1 \sin(-\alpha)}{E} = -\frac{E_1}{E}\sin\alpha. \tag{5}$$

The instantaneous frequency ω follows from Fig. 3. But our first condition implies that the pass band of the plate circuit is so wide that all frequencies are near its center. So we are using only a small central part of the ϕ versus ω curve which approaches a straight line with the slope

$$A = \frac{d\phi}{d\omega}\cdot \tag{6}$$

Then, if ω_0 is the free frequency, the phase angle for another frequency ω close to it will be

$$\phi = A(\omega - \omega_0). \tag{7}$$

The instantaneous beat frequency $\Delta\omega$ is the difference between ω and the impressed frequency ω_1. Setting again $\Delta\omega_0 = \omega_0 - \omega_1$, we have

$$\phi = A(\omega - \omega_0) = A\left[(\omega - \omega_1) - (\omega_0 - \omega_1)\right] = A\left[\Delta\omega - \Delta\omega_0\right]. \tag{8}$$

Now, substituting (5) on the left and (4) on the right, we find

$$-\frac{E_1}{E}\sin\alpha = A\left[\frac{d\alpha}{dt} - \Delta\omega_0\right] \tag{9a}$$

and substituting

$$B = \frac{E_1}{E}\cdot\frac{1}{A}$$

we obtain

$$\frac{d\alpha}{dt} = -B\sin\alpha + \Delta\omega_0. \tag{9b}$$

Adding the impressed frequency ω_1 on both sides, we may also write

$$\omega = -B\sin\alpha + \omega_0. \tag{9c}$$

This means physically that the instantaneous frequency is shifted from the free-running frequency by an amount proportional to the sine of the phase angle existing at that instant between the oscillator and the impressed signal. The shift is also proportional to the impressed signal E_1, but inversely proportional to the oscillator grid amplitude E and to the phase versus frequency slope A of the tuned system employed.

For a single tuned circuit, textbooks give

$$\tan\phi = 2Q\frac{\omega - \omega_0}{\omega_0} \tag{10}$$

and for small angles we can write

$$\phi = 2Q\frac{\omega - \omega_0}{\omega_0}\cdot \tag{10a}$$

Hence, substituting into (6)

$$A = \frac{2Q}{\omega_0} \tag{10b}$$

and

$$B = \frac{E_1}{E}\frac{\omega_0}{2Q}\cdot \tag{10c}$$

Equation (9b) reads, therefore, for a single tuned circuit,

$$\frac{d\alpha}{dt} = -\frac{E_1}{E}\frac{\omega_0}{2Q}\sin\alpha + \Delta\omega_0. \tag{11}$$

The possibility of a steady state is immediately apparent; $(d\alpha/dt)$ must then be zero, so that in the steady state

$$0 = -\frac{E_1}{E}\frac{\omega_0}{2Q}\sin\alpha + \Delta\omega_0 \tag{12a}$$

or

$$\sin\alpha = 2Q\frac{E}{E_1}\cdot\frac{\Delta\omega_0}{\omega_0}\cdot \tag{12b}$$

This gives the stationary phase angle between oscillator and impressed signal. Since $\sin\alpha$ can only assume values between +1 and −1, no steady state is possible if the right side of (12b) is outside this range. This gives the condition for synchronization

$$\left|2Q\frac{E}{E_1}\cdot\frac{\Delta\omega_0}{\omega_0}\right| < 1 \qquad (13a)$$

or

$$\frac{E_1}{E} > 2Q\left|\frac{\Delta\omega_0}{\omega_0}\right|. \qquad (13b)$$

Because of its practical importance for receiver applications, another form of this condition shall be considered. E is the voltage which the oscillator (Fig. 1) produces across its grid coil; but if a locked oscillator is used to replace an amplifier, the voltage E_p across the plate circuit is the one that matters, since (E_p/E_1) represents the total gain. Now the tuned circuit is equivalent to a plate load $R_p = Q\sqrt{(L/C)}$, so that for a given transconductance g_m

$$E_p = E\cdot g_m\cdot Q\sqrt{\frac{L}{C}}\cdot$$

Combining this with (13b), we obtain

$$\frac{E_p}{E_1} < \left|\frac{\omega_0}{2\Delta\omega_0}\right|\cdot g_m\sqrt{\frac{L}{C}}\cdot \qquad (13c)$$

It is interesting to note that Q, the only circuit constant entering into (13b) where the grid voltage E is of interest, cancels out in (13c) where the plate voltage E_p is determined.

For an oscillator which contains a plate load other than a simple tuned circuit, the condition for synchronization may be written

$$\frac{E_1}{E} > \left|A\Delta\omega_0\right| \qquad (13d)$$

whereby $A = (d\phi/d\omega)$ for the particular type of plate load.

IV. APPROXIMATION FOR THE PULL-IN PROCESS

Turning now to the transient solution of the differential equation (9b), we examine first the case $\Delta\omega_0 = 0$. This means that the free-running frequency equals that of the impressed signal and that locking will eventually occur for any combination of voltages and circuit constants as evidenced by all forms of (13).

The equation

$$\frac{d\alpha}{dt} = -B\sin\alpha \qquad (14a)$$

shows what happens when the external signal E_1 is suddenly switched on with an initial lag α_1 behind the free-running oscillator. Equation (14a) is quite similar to

$$\frac{d\alpha}{dt} = -B\alpha \qquad (14b)$$

and actually goes over into this form when α is small. Equation (14b) has the familiar solution

$$\alpha = \alpha_1\epsilon^{-Bt} \qquad (14c)$$

and this means physically that the oscillator phase "sinks" toward that of the impressed signal, first approximately, and later accurately as a capacitor discharges into a resistor. The speed of this process, according to (10c) which defines B, is proportional to the ratio of impressed voltage to oscillator voltage and to the bandwidth of the tuned circuit.

If the free-running frequency is not equal to that of the impressed signal, but close enough to permit locking for a given combination of constants according to (13), the manner in which the steady state is reached must still resemble a capacitor discharge. It is particularly worth noting that the final value α_∞ is always approached from one side in an aperiodic fashion. The accurate solution for this case will be given later.

V. PHENOMENA OUTSIDE THE LOCKING RANGE

To obtain a general solution giving α as a funcion of time, it is necessary to integrate (9b). We first substitute

$$K = \frac{\Delta\omega_0}{B} \qquad (15a)$$

which means for a single tuned circuit

$$K = 2Q\frac{E}{E_1}\,\frac{\Delta\omega_0}{\omega_0}\cdot \qquad (15b)$$

By comparing with (13a) and (13d), we find that the condition for synchronization can now be written

$$|K| < 1. \qquad (15c)$$

Substituting into (9b) we obtain

$$\frac{d\alpha}{dt} = -B(\sin\alpha - K). \qquad (16)$$

Integration gives

$$\tan\frac{\alpha}{2} = \frac{1}{K} + \frac{\sqrt{K^2-1}}{K}\tan\frac{B(t-t_0)}{2}\sqrt{K^2-1} \qquad (17a)$$

or

$$\alpha = 2\tan^{-1}\left[\frac{1}{K} + \frac{\sqrt{K^2-1}}{K}\tan\frac{B(t-t_0)}{2}\sqrt{K^2-1}\right] \qquad (17b)$$

wherein t_0 is an integration constant.

Let us now assume that the condition for synchronization is not fulfilled, so that $|K| > 1$. This makes $\sqrt{K^2-1}$ real. With continually increasing t, the term $[B(t-t_0)/2]\sqrt{K^2-1}$ will pass through $\pi/2$, $3\pi/2$, etc., and the tangent on the right side of (17a) will become $+\infty$, $-\infty$, etc. in succession; at these instants $\alpha/2$ must also be $\pi/2$, $3\pi/2$, etc., although it will assume values different from $[B(t-t_0)/2]\sqrt{K^2-1}$ during the intervals.

So, while $[B(t-t_0)/2]\sqrt{K^2-1}$ increases uniformly with time, $\alpha/2$ will grow at a periodically varying rate; but the total length of a period must be the same for both. The average angular beat frequency—the actual number of beats in 2π seconds—is therefore

$$\overline{\Delta\omega} = B\sqrt{K^2-1} \tag{18a}$$

or, substituting from (15a),

$$\overline{\Delta\omega} = \Delta\omega_0 \frac{\sqrt{K^2-1}}{K}. \tag{18b}$$

$\Delta\omega_0$ is that beat frequency which would appear if the oscillator maintained its free frequency; $\sqrt{K^2-1}/K$ approaches unity for large values of K, far from the point where locking occurs; but it drops toward zero when this point ($K=1$) is approached.

Fig. 4 shows a plot of the average beat frequency $\overline{\Delta\omega}$ versus the undisturbed beat frequency $\Delta\omega_0$ as computed from (18b).

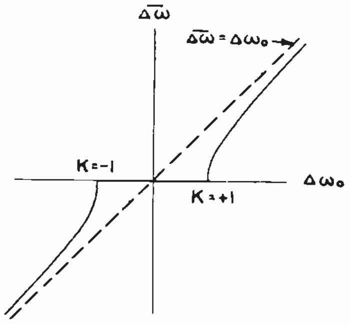

Fig. 4—Reduction of beat frequency due to locking.

In the intervals between the arguments $\pi/2$, $3\pi/2$, etc., the two angles in (17a) cannot be the same because of the factor $\sqrt{K^2-1}/K$ with which one tangent is multiplied, and the addition of $1/K$. For large values of K, $1/K$ vanishes and the factor approaches unity, so that the rate of increase of $\alpha/2$ with time will vary by a smaller percentage as the beat frequency increases; but (16) shows that $d\alpha/dt$ must still vary between $B(K-1)$ and $B(K+1)$. Now, $BK=\Delta\omega_0$, according to (15), and B represents the highest difference $\Delta\omega_{\max}$ for which locking can occur ($K=1$ for $B=\Delta\omega_0$). So the instantaneous beat frequency $\Delta\omega$ will vary periodically between $\Delta\omega_0-\Delta\omega_{\max}$ and $\Delta\omega_0+\Delta\omega_{\max}$ as long as $\Delta\omega_0$ exceeds $\Delta\omega_{\max}$.

$\Delta\omega_{\max}$ itself is determined by (13). It is

$$\Delta\omega_{\max} = \frac{\omega_0}{2Q}\,\frac{E_1}{E} \tag{19a}$$

or

$$\Delta\omega_{\max} = \frac{\omega_0}{2}\,\frac{E_1}{E_p}\,g_m\sqrt{\frac{L}{C}} \tag{19b}$$

for a single-tuned circuit, and

$$\Delta\omega_{\max} = \frac{1}{A}\cdot\frac{E_1}{E} \tag{19c}$$

for any type of plate load for which $A=d\phi/d\omega$.

If K is only slightly above unity, the factor $\sqrt{K^2-1}/K$ falls far below unity, and the phase angle between E_1 and E increases at an extremely nonuniform rate. Inspection of the vector diagram in Fig. 2 gives the resultant grid voltage $E_g=E-E_1\cos\alpha$. To illustrate the wave form of the resultant beat note

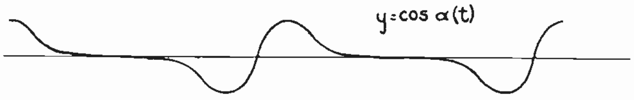

Fig. 5—Wave form of beat note for $\cos\alpha(t)$.

the function $\cos\alpha(t)$ is plotted in Fig. 5. Operation very close to locking is assumed. Other wave forms are possible in beat-frequency oscillators where the beat note is produced in a separate detector; a constant phase shift may then be added to α on the way to the detector. Fig. 6 shows an example with a phase shift of $\pi/2$: the

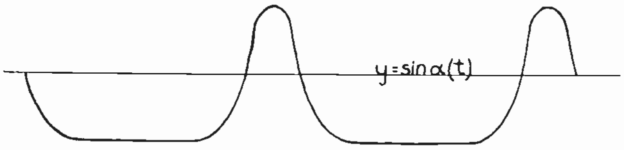

Fig. 6—Wave form of beat note for $\cos\left[\alpha(t)+\frac{\pi}{2}\right]$.

function plotted is $\cos[\alpha(t)+\pi/2]$ which equals $-\sin\alpha(t)$.

VI. ACCURATE ANALYSIS OF THE PULL-IN PROCESS

To make the discussion of (17a) complete, we may finally apply it to the case of an oscillator pulling into the locked condition, $|K|<1$. The term $\sqrt{K^2-1}$ then becomes $j\cdot\sqrt{1-K^2}$. By use of the relation $\tanh x = -j\tan jx$, equation (17a) is transformed[13] into

$$\tan\frac{\alpha}{2} = \frac{1}{K} - \frac{\sqrt{1-K^2}}{K}\tanh\frac{B(t-t_0)}{2}\sqrt{1-K^2}. \tag{20a}$$

The integration constant t_0 permits one to fit the equation to the initial phase difference α_1, which exists when the external signal is switched on.

As t increases, the functions tanh and coth go assymptotically toward unity. The steady state must therefore be given by

$$\tan\frac{\alpha}{2(\infty)} = \frac{1-\sqrt{1-K^2}}{K}. \tag{20b}$$

Using (16) we identify K with $\sin\alpha_\infty$ for the steady state. Hence $\sqrt{1-K^2}=\cos\alpha_\infty$ and (20b) becomes $(1-\cos\alpha_\infty)/\sin\alpha_\infty$, which is indeed equal to $\tan(\alpha_\infty/2)$ by a trigonometrical identity.

VII. A MECHANICAL MODEL

In conclusion, let us construct a mechanical model to

---

[13] Equation (20a) holds for $\sin\alpha_1>k$. Otherwise, substitute coth for tanh.

illustrate the processes which we have derived. To provide a full analogy, the model must follow the same differential equation (9b)

$$\frac{d\alpha}{dt} = -B \sin \alpha + \Delta\omega_0.$$

Let us forget $\Delta\omega_0$ for the moment. A pendulum in a viscous fluid would follow the remaining equation if α is taken to mean the angle between the pendulum and a vertical line. If we assume the viscosity of the fluid to be so great that we need not consider the inertia of the pendulum, the angular speed of the pendulum $d\alpha/dt$ is proportional to the force which causes it to move. We may shape the pendulum so that one unit of force will produce one unit of speed. Now, if B is the weight of the pendulum, the force acting to return it to its rest position will indeed be $-B \sin \alpha$.

To include the term $\Delta\omega_0$, we must add a constant force. We may also bring $\Delta\omega_0$ over to the left side of the equation; since $d\alpha/dt$ stands for angular speed, $-\Delta\omega_0$ on the left would mean a constant backward rotation of the pendulum with respect to the liquid. Constant forward rotation of the liquid with respect to the pendulum would produce the same force, and we choose this interpretation for our model shown in Fig. 7.

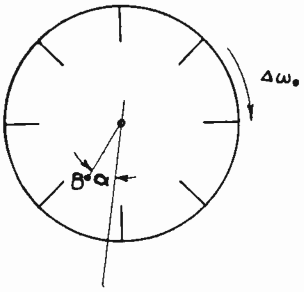

Fig. 7—Mechanical model: pendulum in a rotating container filled with viscous liquid.

The viscous liquid is enclosed in a drum rotating with an angular speed $\Delta\omega_0$. Again we assume that the viscosity of the liquid is so great that it will follow the rotation of the drum completely. Let us also assume that the rotation of the liquid is not noticeably affected by inserting the pendulum.

Remembering now that the vertical direction represents the phase of the impressed signal, while the position of the pendulum indicates the relative phase of the oscillator grid voltage, we can go through the whole range of phenomena by rotating the drum with various speeds, corresponding to the undisturbed beat frequencies $\Delta\omega_0$.

At low drum speed, the pendulum will come to rest at a definite angle α_∞ which will increase as the drum speed rises. If disturbed, the pendulum will "sink" back; it will never go past the rest position since inertia effects are absent.

If we lift the pendulum clockwise to any point below $\alpha_1 = \pi - \alpha_\infty$, it will come back counterclockwise; but if we lift it past this limit, or over to the right, it will return clockwise. This is the reason why there are two different transient solutions for (20a).

At a certain critical drum speed $\Delta\omega_{\max} = B$ the pendulum will stand horizontal; if the drum is further accelerated, it will "unlock" and begin to go around, moving fast on the right but very slow on the left and completing a much smaller number of revolutions than the liquid.

But as we increase the speed further, the fast whirling fluid takes the pendulum along, irrespective of the weight. The motion appears much more uniform, and the speed of the pendulum becomes nearly equal to that of the drum: the average beat frequency $\overline{\Delta\omega}$ is approaching the undisturbed value $\Delta\omega_0$.

ACKNOWLEDGMENT

C. W. Carnahan and H. P. Kalmus, in the course of their work on locked oscillators for frequency-modulation receivers,[1] assembled a great deal of information regarding the behavior of such oscillators inside and outside the locking range. To study these phenomena further, they built a 1000-cycle oscillator which permitted direct observation of phase and amplitude variations on the oscilloscope. They investigated the influence of time constants and, among other effects mentioned in this paper, observed the large amplitude modulation which occurs when the time constant of the grid bias is large (case of "infinite Q" noted in Section II). Discussion of these experiments laid the groundwork for the analysis presented here, and the author gratefully acknowledges this important contribution.

Correspondence

A Correction Formula for Voltmeter Loading

The writer has derived an equation which may be of interest to some of the members of The Institute of Radio Engineers. This equation corrects for the loading produced by current-operated (D'Arsonval) voltmeters. This derivation is believed to be original; however, it seems likely that such an expression may have been used in the past. If any members are acquainted with the following method of determining the true voltage between two terminals, it will be appreciated if they contact the writer giving the source of information.

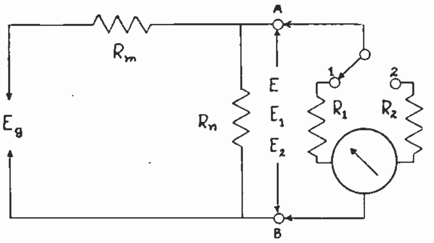

Fig. 1

Consider the basic circuit of Fig. 1.

Let E = true voltage between terminals A and B with the voltmeter disconnected
E_1 = voltage measured on the highest range that will give an accurate reading
E_2 = voltage measured on the next range lower than used for E_1
E_g = source voltage of constant magnitude
R_1 = internal resistance of voltmeter when measuring E_1
R_2 = internal resistance of voltmeter when measuring E_2
S = ratio of the two scales used ($S = R_1/R_2$)
R_n = resistance across which output voltage is developed
R_m = series-dropping resistance that accounts for the differences among E, E_1, and E_2.

Simple circuit theory allows us to write

$$E = E_g \frac{R_n}{R_m + R_n}$$

then

$$E_1 = E_g \frac{R_1 R_n}{R_1 R_m + R_1 R_n + R_m R_n}$$

or

$$E_1 = E \frac{R_m + R_n}{R_m + R_n + (R_m R_n / R_1)} \tag{1}$$

likewise

$$E_2 = E \frac{R_m + R_n}{R_m + R_n + (R_m R_n / R_2)} . \tag{2}$$

Substituting SR_2 for R_1 in (1) and solving for E in both equations, we have

$$E = E_1 \frac{R_m + R_n + (R_m R_n / SR_2)}{R_m + R_n} \tag{3}$$

$$E = E_2 \frac{R_m + R_n + (R_m R_n / R_2)}{R_m + R_n} . \tag{4}$$

Rearranging (3) and (4),

$$(R_m + R_n)(E - E_1) = E_1 \frac{R_m R_n}{SR_2} \tag{5}$$

$$(R_m + R_n)(E - E_2) = E_2 \frac{R_m R_n}{R_2} . \tag{6}$$

Dividing (5) by (6),

$$SE_2(E - E_1) = E_1(E - E_2).$$

Thus,

$$E = \frac{(S-1)E_1}{S - (E_1/E_2)} = \left\{ \begin{matrix} \text{true voltage be-} \\ \text{tween } A \text{ and } B \end{matrix} \right\} . \tag{7}$$

The equation, when written in this form, is particularly suited for slide-rule calculations. Furthermore, if the scale ratio S can be made equal to 2.0, then the equation simplifies to

$$E = \frac{E_1}{2 - (E_1/E_2)} .$$

Example: A voltmeter, when placed across two terminals, reads 105 volts on its 200-volt range. The voltmeter is switched to its 100-volt range and measures 70 volts.

$$E = \frac{105}{2 - (105/70)} = \frac{105}{2 - 1.5} = 210 \text{ volts.}$$

The correction factor given by (7) can be used for either alternating or direct-current circuits. The only restrictions are that the measurements be made in circuits that are linear and the voltmeter must be of the type in which the internal resistance is directly proportional to the selected range.

The question arises as to how well the equation will apply to circuits with vacuum tubes. Placing a current-operated voltmeter between the element of a tube and ground will lower the voltage on that element. It is important to know how the resistance of that element is affected when this happens. Experiment shows that the following is true: (1) When the tube is operated with fixed bias the element resistance changes radically with changes in element potential and the correction factor cannot be used. (2) When cathode bias is employed, the reduction in element voltage is accompanied by a reduction in current. Thus the resistance remains substantially constant within the normal operating range of the tube and the equation may be used, but with reserve. The resulting error is usually less than 5 per cent, but errors as high as 14 per cent have been observed when making measurements in vacuum-tube circuits with a voltmeter sensitivity of 1000 ohms per volt. However, the error before correcting for voltmeter loading was in the order of 60 per cent for these cases.

In rare cases, the internal resistance of ammeters may cause a small error to exist between the measured current and the current that flows with the meter out of the circuit. It is possible to correct for this with an equation similar to equation (7). Consider the circuit shown in Fig. 2.

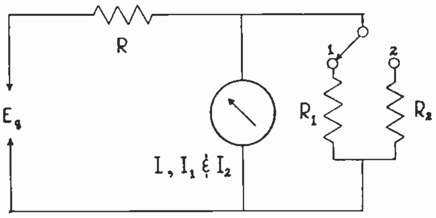

Fig. 2

Let I = actual current that flows in the absence of the ammeter
I_1 = current measured on the highest range that will give an accurate reading
I_2 = current measured on the next range lower than used for I_1
E_g = source voltage of constant magnitude
R_1 = internal resistance of the ammeter when measuring I_1
R_2 = internal resistance of the ammeter when measuring I_2
R = circuit resistance
S = ratio of the two scales used. ($S = R_2/R_1$) (Note that for S to be greater than 1.0, the ratio must be the opposite to that used for voltmeters.)

Looking at the circuit, we can write

$$I = \frac{E}{R}$$

also

$$I_1 = I \left(\frac{1}{1 + (R_1/R)} \right) \tag{8}$$

and

$$I_2 = I \left(\frac{1}{1 + (R_2/R)} \right) . \tag{9}$$

Substituting SR_1 for R_2 in (9) and solving for R in both equations,

$$R = \frac{R_1 I_1}{I - I_1} = \frac{SR_1 I_2}{I - I_2} . \tag{10}$$

Solving for I, we have

$$I = \frac{(S-1)I_1}{S - (I_1/I_2)} . \tag{11}$$

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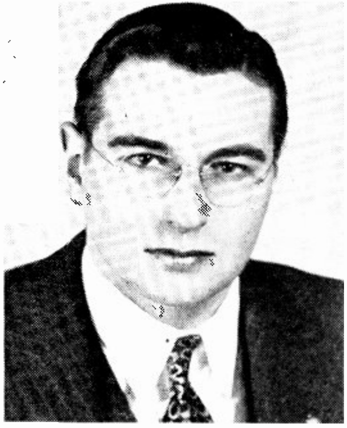
Contributors to Proceedings of the I.R.E.



C. L. Dolph

C. L. Dolph was born at Ann Arbor, Michigan, in 1918. He received the B.A. degree in mathematics from the University of Michigan in 1939, and the Ph.D. degree in mathematics from Princeton University in 1944. From 1940 to 1943 he was an instructor in mathematics at Princeton University. From 1943 to 1946 he was a member of the radio division of Naval Research Laboratory. He has recently joined the technical staff of Bell Telephone Laboratories.

Dr. Dolph is a member of Phi Beta Kappa, Sigma Xi, and the American Mathematical Society.

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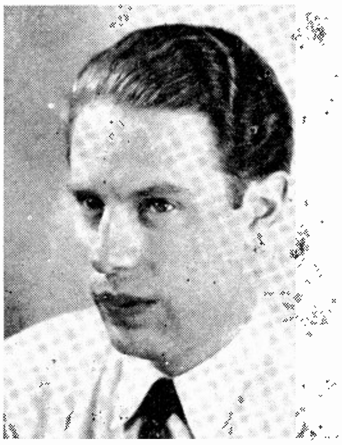

Robert Adler

Robert Adler (A'42) was born on December 4, 1913, at Vienna, Austria. He received the Ph.D. degree in physics in 1937, from the University of Vienna, and was assistant to a patent attorney in Vienna the following year. From 1939 to 1940, he worked for Scientific Acoustics, Ltd., London, England. After one year with Associated Research, Inc., in Chicago, he joined the research group of Zenith Radio Corporation in Chicago, and has remained with that organization to date.

During 1942 and 1943, Dr. Adler was engaged in work on high-frequency magnetostrictive oscillators. More recently, he was active in the vacuum-tube field through his development of the phasitron system of frequency modulation.

⁂

Heinz E. Kallmann

Heinz E. Kallmann (A'38–M'41–SM'43) was born on March 10, 1904, at Berlin, Germany. He received his Ph.D. degree from the University of Goettingen in 1929. From 1929 to 1934, Dr. Kallmann was a research engineer in the laboratories of the C. Lorenz A. G., and from 1934 to 1939 he was an engineer in the television research and design department of Electric and Musical Industires, Ltd. Hayes, England. Dr. Kallmann is now a consulting engineer in New York City. During 1940, he was a member of the New York Laboratory Staff of Scophony Television, Ltd. From 1943 to 1945 he was a member of the staff of the Radiation Laboratory, Massachusetts Institute of Technology.

⁂

James F. Gordon (A'44) was born on April 10, 1912, at Helena, Montana. After graduation from high school he entered radio and refrigeration maintenance and installation work. From 1937 to 1941 he was engaged in the design and installation of electronic and allied equipment. In 1941 he joined the United States Signal Corps as civilian engineer and served as instructor in several Signal Corps schools. He joined the research staff of Bendix Radio in 1943. Since that time he has been active in the development of new electronic products.

James F. Gordon

Chicago Engineering

Official People

Left to right are W. O. Swinyard (A'37-M'39-SM'43), W. L Everitt (A'25-M'29-F'38), and Cullen Moore (A'37-VA'39-SM'44).

Approximately 500 guests registered for the Engineering Conference held by the Chicago Section of The Institute of Radio Engineers on February 9, 1946. Dr. William L. Everitt, junior past president of the I.R.E., delivered the opening address. Four technical sessions held during the day, a buffet luncheon, and the displays of 35 exhibitors were features of the meeting. The Conference was climaxed by the fourth annual banquet of the Chicago Section. Mr. Kenneth W. Jarvis presented a talk on "Those Things Which Make a Radio Engineer." Entertainment and dancing concluded the evening. The conference was a highly successful one, and the results were encouraging to the membership of the Chicago Section.

Summaries and titles of the technical papers presented follow.

DEFLECTION-TYPE HIGH-VOLTAGE SUPPLIES FOR TELEVISION RECEIVERS

Madison Cawein

(Farnsworth Television and Radio Corporation, Ft. Wayne, Indiana)

The development of high-voltage power supplies in which the horizontal-deflection return pulse is rectified to provide a low-power source of direct current was discussed. The practical design of a high-voltage and deflection transformer was featured, and a brief discussion of deflection theory given.

INTERESTING APPLICATIONS OF INDUCTION AND DIELECTRIC HEATING

John A. Callanan

(Illinois Tool Works, Chicago, Illinois)

THE LORAN NAVIGATION SYSTEM

Donald G. Fink

(*Electronics*, New York, New York)

General principles of hyperbolic navigation and its application in the loran system were stressed, and airborne and shipborne equipment, as well as ground stations, were described.

ASPECTS OF FREQUENCY-MODULATION RECEIVER DESIGN

Frank C. Gow

(Industry Service Division, RCA Laboratories, New York, New York)

The many often-little-recognized phases of frequency-modulation receiver design were reviewed. Attention was focused solely on considerations of general interest, such as oscillator stability, intermediate-frequency phase-shift characteristics and their relation to amplitude disturbances, radio-frequency tuning systems, the Seeley ratio detector, and automatic-frequency-control applications.

THE PRACTICAL ASPECTS OF INTERMODULATION AND APPLICATION TO DESIGN, TESTING, AND MAINTENANCE OF AUDIO SYSTEMS

John K. Hilliard

(Altec Lansing Corporation, Hollywood, California)

Intermodulation test equipment consisting of a signal generator and an intermodulation analyzer were described. The basic theory of the apparatus was discussed along with its application to the design and testing of amplifiers, disk and film recording, radio transmitters, and acoustic systems.

Conference Committee Members

Left to right are Karl Kramer (A'41-SM'45), W. O. Swinyard (A'37-M'39-SM'43), F. W. Schor (A'42-SM'45), A. W. Graf (A'26-VA'39-M'44-SM'45), R. T. Van Niman (A'44-M'44), L. E. Packard (M'41-SM'43), and R. E. Samuelson (SM'45).

A Group of Notables

Left to right are D. E. Foster (A'26-M'37-SM'43), W. J. Polydoroff (M'24-SM'43), D. E. Noble (A'25-VA'39-SM'44), E. Wilby, Alfred Crossley (A'19-M'26-SM'43), R. H. Langley (A'12-M'16-F'29), and H. C. Luttgens (A'31-VA'39-SM'44).

Section Conference

RADIO APPLICATIONS FOR T3 SUBMINIATURE TUBES

Walter R. Jones
(Radio Tube Division, Sylvania Electric Products, Inc., Emporium, Pennsylvania)

The design and the electrical characteristics of small tubes and their application in radio equipment were discussed.

RADIO-RECEIVER-RESPONSE TRENDS

Hugh S. Knowles
(Jensen Radio Manufacturing Company, Chicago, Illinois)

Several factors influencing over-all broadcast system response during the past two decades were discussed, and emphasis was placed on the electroacoustic elements in the system and their performance trends. Certain limitations imposed on frequency-modulation systems by acoustic considerations and electroacoustic components were also stressed.

DEVELOPMENTS IN ATOMIC ENERGY

Robert J. Moon
(Executive Committee, Atomic Scientists of Chicago, Chicago, Illinois)

The fundamental principles underlying release of nuclear energy and the design and construction of nuclear-energy devices, such as the pile, the atomic bomb, and the electromagnetic separator, were given. Problems arising as a result of the realization of nuclear energy were analyzed.

VT OR RADIO PROXIMITY FUZES

John M. Pearce
(Applied Physics Laboratory, Johns Hopkins University, Baltimore, Maryland)

AND

Cledo Brunetti
(Project Engineering Section, Ordnance Development Division, National Bureau of Standards, Washington, D. C.)

The design features of battery- and generator-powered VT fuzes, insofar as security regulations permitted, were described.

Speakers
Left to right are Madison Cawein (M'36-SM'43), J. P. Hilliard, F. C. Gow (A'44), and H. S. Knowles (A'25-VA'39-F'41).

A Group of Speakers
Left to right are Cledo Brunetti (A'37-VA'39), J. M. Pearce, D. G. Fink (A'35-VA'39-SM'45), and W. R. Jones (A'26-M'32-SM'42).

HUMAN RELATIONS IN ENGINEERING

Walter D. Kelsey
(Dale Carnegie Institute, Chicago, Illinois)

How the engineer can obtain maximum efficiency from his assistants through co-operative effort and a thorough understanding of human nature was outlined.

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The members of the various committees responsible for the conference are given below.

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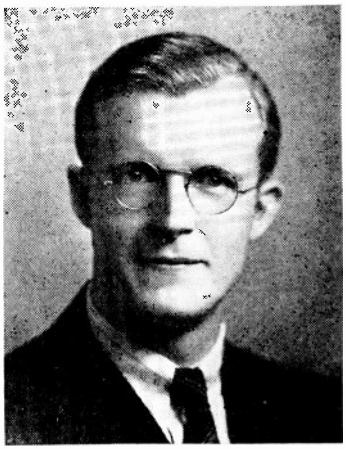

J. D. SCHANTZ

J. D. SCHANTZ

The appointment of J. D. Schantz (A'35–SM'44) as assistant manager of the research department of Farnsworth Television and Radio Corporation, Ft. Wayne, Indiana, was recently announced by B. R. Cummings (A'18–M'20–SM'43), the firm's vice-president in charge of engineering. A graduate of Gettysburg College with a B.S. degree in electrical engineering, Mr. Schantz attended the United States Naval Academy for one and one-half years and Leland Stanford University for one year. He received his M.S. degree in engineering from the University of Michigan.

Mr. Schantz performed research in acoustics, sound recording, facsimile, and omnidirectional radio range at the RCA Victor Manufacturing Company's research department for two and one-half years. He came to Farnsworth in 1939 from Farnsworth Television, Inc., where he conducted research on circuits and television terminal equipment. Mr. Schantz is an Associate Member of Sigma Xi.

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Abstracts and References

The Institute is pleased to announce the inauguration, in this issue of the Institute's journal, of comprehensive Abstracts and References of current engineering and scientific literature in the radio-and-electronic field. This material will be found beginning on page 407. Comments and suggestions of the readers concerning this will be of interest and help to the Editorial Department and should be addressed to

The Institute of Radio Engineers, Inc.
Editorial Department
26 West 58th Street
New York 19, New York

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VWOA SERVICE AWARDS

At the twenty-first Annual Dinner Cruise of the Veteran Wireless Operators Association, held on February 16, 1946, at the Hotel Astor, William J. McGonigle (A'45-M'45), president of the VWOA, presented Marconi Memorial Service Awards to The Institute of Radio Engineers and the American Radio Relay League.

Frederick B. Llewellyn (A'23-F'38), president of the I.R.E., accepted a plaque given "in significance of the conspicuous contributions of radio engineers to the successful prosecution of World War II" on behalf of the Institute. This award will occupy a prominent place in the new building of the Institute at Fifth Avenue at 79th Street.

George W. Bailey (A'38-VA'39), executive secretary of the I.R.E. and président of ARRL, accepted in the League's behalf a plaque given "in recognition of the part played by radio amateurs in the successful prosecution of World War II." This will be displayed at the League's national headquarters in West Hartford, Connecticut.

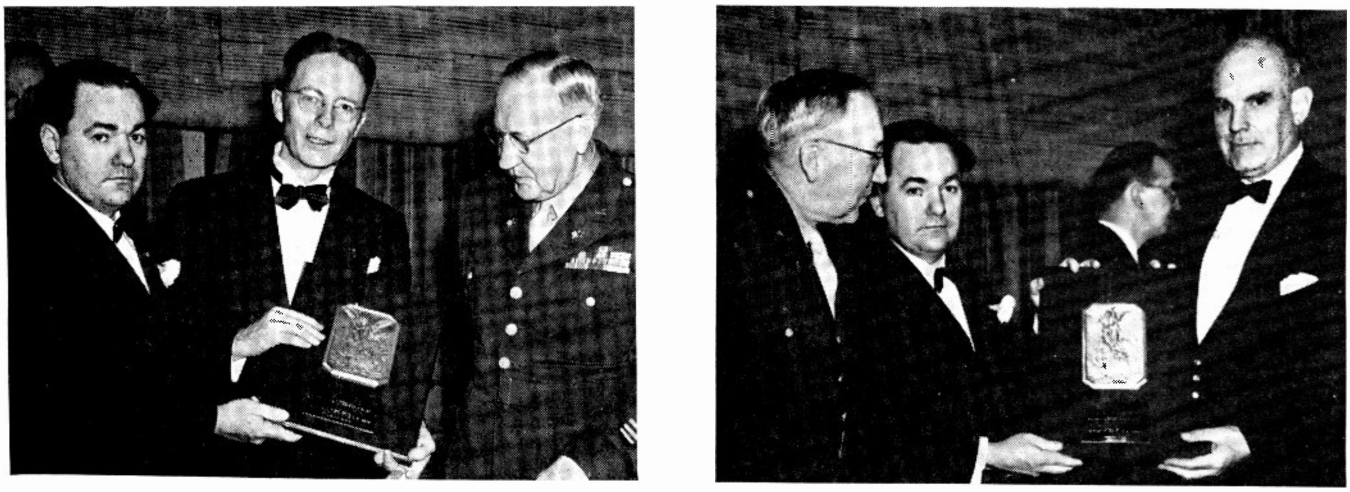
KARL KRAMER

KARL KRAMER

Karl Kramer (A'41–SM'45) has recently been named technical service engineer in the sales department of Jensen Radio Manufacturing Company, Chicago, Illinois. He received his B.E.E. degree from Ohio State University in 1931, and his graduate work, majoring in advanced communications, was performed at that institution where he received his M.Sc. degree in 1933.

Mr. Kramer joined Jensen in 1935 to serve as senior development engineer and applications engineer, and, in this capacity, he has been responsible for direct-radiator loudspeaker development and for the design and development of enclosures. Since his affiliation with the company, he has taken advanced mathematics and physics, with emphasis on subjects related to acoustics, at the University of Chicago and Illinois Institute of Technology.

A member of the Acoustic Society of America and the Radio Engineers Club of Chicago, Mr. Kramer presently serves on the executive committee of the Chicago Section of The Institute of Radio Engineers.



Major General H. C. Ingles looks on while Mr. William J. McGonigle presents VWOA Service Awards to Dr. Frederick B. Llewellyn (left) and Mr. George W. Bailey (right).

I.R.E. People

ADOLPH B. CHAMBERLAIN RECEIVES LEGION OF MERIT MEDAL

Adolph B. Chamberlain (A'27-M'30-F'42), chief engineer of the Columbia Broadcasting System, was awarded the Legion of Merit medal by Navy Secretary James Forrestal on February 27, 1946. The citation reads as follows: "For exceptionally meritorious conduct in the performance of outstanding services to the Government of the United States as Assistant Head of the Design Branch, Electronics Division, Bureau of Ships, from April to October, 1945. Exercising consistent ingenuity, patience, and judgment, Captain Chamberlain succeeded in breaking a tremendous design and production deadlock at a time when airborne radar equipment was urgently needed by the Fleet to combat enemy air action. By his expert professional ability and his tactful, persistent efforts in the fulfillment of an extremely difficult assignment, Captain Chamberlain was personally responsible for the expeditious completion and delivery of radar and countermeasures to the Fleet despite numerous technical problems, and his conduct throughout reflects great credit upon himself and the United States Naval Service."

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DR. LLEWELLYN ATTENDS CONVENTION IN LONDON

At the invitation of the Institution of Electrical Engineers, Dr. F. B. Llewellyn, president of the Institute of Radio Engineers, was their guest at the Radiolocation Convention in London on March 26 to 29, 1946, which was the occasion for the presentation of a large number of technical papers on radar and on radio navigation. The Convention was opened by the Right Honorable John Wilmot, M.P., British Minister of Supply, whose remarks were followed by a paper on "The Evolution of Radiolocation" by Sir Robert Watson Watt. Dr. Llewellyn then brought greetings from The Institute of Radio Engineers. In his talk he dwelt upon the co-operation which existed during the war between engineers in England and America, and gave examples to show how joint effort along technical lines produced a more rapid development than would have been obtained by independent effort. He closed with a plea for a continuation of co-operative effort between engineers everywhere in order to further the causes of peace, and anticipated that the Institution of Electrical Engineers, in England, and The Institute of Radio Engineers, with headquarters in America, working together and with other organizations having similar aims and purposes, would provide the means through which this co-operative effort can be carried forward.

Following this opening session, on the evening of March 26, there was a dinner with the Council of the Institution of Electrical Engineers. During the ensuing three days of the Convention, Dr. Llewellyn had a number of conferences with officers of the British Institution and members of its operating staff. The subjects discussed ranged all the way from questions of handling dues of I.R.E. members residing in England to the matters of exchanging abstracts of papers intended for publication at later dates and the organization and method of functioning of various types of technical committees.

Following the close of the Convention, Dr. Dunsheath, president of the Institution of Electrical Engineers made a presentation of an engraved silver tray to Dr. Llewellyn in behalf of the friends he had made in the Institution of Electrical Engineers.

Before his return to the United States, Dr. Llewellyn took the occasion to visit a number of the industrial and university research establishments in England, and was entertained both in Oxford and in Cambridge. On the evening preceding the Convention, he went on the air over the British Broadcasting Company with greetings from the I.R.E.

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January, 1946, copies of the PROCEEDINGS OF THE I.R.E. AND WAVES AND ELECTRONS, in good condition, will be purchased by The Institute of Radio Engineers at 50 cents a copy.

DAVID SARNOFF RECEIVES MEDAL FOR MERIT

The Medal for Merit was presented on March 18, 1946, to Brigadier General David Sarnoff (A'12-M'14-F'17), president of the Radio Corporation of America, by Major General H. C. Ingles, representing President Truman. The citation reads as follows: "David Sarnoff, for exceptionally meritorious conduct in the performance of outstanding services to the United States as president, Radio Corporation of America, from October, 1942, to March, 1944. Mr. Sarnoff placed the full resources of his company at the disposal of the Army whenever needed, regardless of the additional burden imposed upon his organization. He encouraged key personnel to enter the service, and at his direction, RCA engineers and technicians rendered special assistance on numerous complex communications problems. He fostered electronic advances which were adapted to military needs with highly beneficial results. The wholehearted spirit of co-operation which Mr. Sarnoff inculcated in his subordinates was of inestimable value to the war effort."

General Sarnoff was previously awarded the Legion of Merit medal in 1944 for "exceptional meritorious conduct in the performance of outstanding service" when he was on military service overseas.

Major General H. C. Ingles presents Medal for Merit to Brigadier General David Sarnoff.

I.R.E. People

Arthur L. Samuel

Arthur L. Samuel

Arthur L. Samuel (A'24–SM'44–F'45) recently has been appointed professor of electrical engineering at the University of Illinois, where he will concern himself largely with research and development work on electron tubes, and the direction of graduate work in this field.

Dr. Samuel was born on December 5, 1901, in Emporia, Kansas. He received the A.B. degree in mathematics from the College of Emporia in 1923, and was enrolled in the co-operative course in electrical engineering at the Massachusetts Institute of Technology from 1923 to 1926, receiving the S.B. degree in 1925 and the S.M. degree in 1926. He has taken additional graduate work both at M.I.T. in electrical engineering and at Columbia University in physics, and recently was awarded the honorary degree of Sc.D. from the College of Emporia.

In addition to his work with the General Electric Company in connection with the co-operative course from M.I.T., Dr. Samuel was an employee of the General Electric Company prior to entering M.I.T. and again during the summer of 1927. Most of this time was spent in research and development work. After two years as an instructor in electrical engineering at M.I.T., he became a member of the technical staff at the Bell Telephone Laboratories where he has been continually engaged in research and development work on electron tubes. From 1928 to 1931 he was active in the development of gas rectifiers and thyratrons. Since 1931 his chief interest has been in the development of vacuum tubes for use at ultra-high frequencies. He is well known for his technical papers and patents in this field, having made contributions in the development of Barkhausan tubes, magnetrons, space-charge-controlled triodes and pentodes for ultra-high frequencies, velocity-variation oscillators and amplifiers, and transmit-receive gas switching tubes.

Dr. Samuel is a member of the American Physical Society, the American Association

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W. C. Freeman, Jr. 2018 Reed St. Williamsport 39, Pa.	Williamsport September 4	S. R. Bennett Sylvania Electric Products, Inc. Plant No. 1 Williamsport, Pa.

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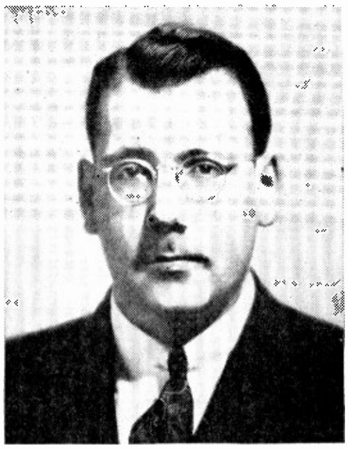
I.R.E. People



Clinton B. DeSoto

Clinton B. DeSoto

On April 1, 1946, Clinton B. DeSoto (M'46) assumed the duties of technical editor of The Institute of Radio Engineers. Born in Ogilvie, Minnesota, in 1912, he attended the University of Wisconsin School of Journalism.

Mr. DeSoto became a licensed radio amateur in 1926, and in 1930 he joined the American Radio Relay League headquarters staff as assistant to the secretary. In 1936 he was appointed assistant secretary of the League, and in 1942 was transferred to the editorial staff as assistant editor of *QST*. Mr. DeSoto became executive editor of *QST* in 1943, and editor in 1944.

The author of a number of books and magazine articles dealing with radio topics, Mr. DeSoto handled the revision and production of the 1943, 1944, and 1945 editions of "The Radio Amateur's Handbook." He has also been associated with the development of radio remote-control systems for military and amateur applications. He served as secretary of the Connecticut Valley Section of The Institute of Radio Engineers from 1933 to 1936.

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for the Advancement of Science, and the American Institute of Electrical Engineers. He has long been active in the affairs of the Institute of Radio Engineers, and he received the best papers prize for 1937. He was chairman of the 1946 Electron-Tube Conference Committee and is at present a member of the Technical Committee on Electron Tubes, the Symbols Committee, and is chairman of the Subcommittee on Advanced Developments.

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Robert Hampshire
T. J. McCarthy
Eugene Mittelmann
H. L. Palmer
F. K. Priebe
W. C. Rudd
V. W. Sherman
Douglas Venable
C. H. Warriner
D. E. Watts
Julius Weinberger
T. L. Wilson
P. D. Zottu

Navigation Aids

D. G. Fink, *Chairman*

Henri G. Busignies
P. A. D'Orio
R. C. Ferrar
A. B. Hunt
H. R. Mimno
G. H. Phelps
John Rankin
P. C. Sandretto
R. R. Welsh

Piezoelectric Crystals

W. G. Cady, *Chairman*

C. F. Baldwin
F. A. Barrow
W. L. Bond
J. K. Clapp
Clifford Frondel
Paul Gerber
E. W. Johnson
W. P. Mason
P. L. Smith
R. A. Sykes
K. S. Van Dyke
Sidney Warner
J. M. Wolfskill

Radio Receivers

D. E. Foster, *Chairman*

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W. L. Carlson
W. F. Cotter
L. F. Curtis
W. L. Dunn
H. C. Forbes
C. J. Franks
A. R. Hodges
J. K. Johnson
C. R. Miner
Garrard Mountjoy
H. O. Peterson
J. M. Pettit
F. H. R. Pounsett
John Reid
R. F. Shea
R. M. Wilmotte
C. F. Wolcott

Research

F. E. Terman, *Chairman*

W. L. Barrow
Fred Bowditch
R. M. Bowie
E. W. Engstrom
W. L. Everitt
D. G. Fink
H. T. Friis
Norman Snyder
L. C. Van Atta
A. F. Van Dyck
Julius Weinberger

Radio Transmitters

E. A. Laport, *Chairman*

M. R. Briggs
H. R. Butler
Harry Diamond
F. A. Gunther
W. E. Jackson
L. A. Looney
W. W. Lindsay
J. F. Morrison
J. C. Schelleng
Robert Serrell
D. B. Sinclair
I. R. Weir
J. E. Young

Radio Wave Propagation and Utilization

J. A. Stratton, *Chairman*

S. L. Bailey
C. R. Burrows
T. J. Carroll
A. E. Cullum
W. S. Duttera
D. E. Kerr
H. O. Peterson
J. A. Pierce
S. A. Schelkunoff
George Sinclair
R. L. Smith-Rose
H. W. Wells
J. W. Wright

Railroad and Vehicular Communication

D. E. Noble, *Chairman*

A. E. Abel
George Brown
T. G. M. Brown
Frederick Budelman
F. C. Collings
W. T. Cooke
P. R. Kendall
C. N. Kimball, Jr.
G. H. Phelphs
F. M. Ryan
Winfield Salisbury
Frank Walker

Standards

R. F. Guy, *Chairman*

R. S. Burnap
W. G. Cady
P. S. Carter
A. B. Chamberlain
I. S. Coggeshall
M. G. Crosby
Eginhard Dietze
D. G. Fink
D. E. Foster
H. C. Gillespie
V. M. Graham
E. A. Guillemin
Keith Henney
L. C. F. Horle
E. A. Laport
Knox McIlwain
D. E. Noble
E. W. Schafer
H. L. Spencer
J. A. Stratton
F. E. Terman
H. M. Turner
H. A. Wheeler
L. E. Whittemore
C. J. Young

Symbols

E. W. Schafer, *Chairman*

A. E. Anderson
R. R. Batcher
M. R. Briggs
R. S. Burnap
C. R. Burrows
H. F. Dart
J. H. Dellinger
E. T. Dickey
H. S. Knowles
O. T. Laube
C. D. Mitchell
C. A. Nietzert
A. F. Pomeroy
A. L. Samuel
J. R. Steen
H. M. Turner
H. A. Wheeler

Television

I. J. Kaar, *Chairman*

W. F. Bailey
J. E. Brown
F. L. Burroughs
K. A. Chittick
D. G. Fink
D. E. Foster
P. C. Goldmark
T. T. Goldsmith, Jr.
R. N. Harmon
A. G. Jensen
R. D. Kell
C. D. Kentner
P. J. Larsen
L. M. Leeds
Leonard Mautner
Jerry Minter
Garrard Mountjoy
J. A. Ouimet
D. W. Pugsley
R. E. Shelby
D. B. Sinclair
D. B. Smith
M. E. Strieby

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Alabama Polytechnic Institute: Appointment Later
Alberta, University of: J. W. Porteous
Arkansas, University of: Appointment Later

British Columbia, University of: H. J. MacLeod
Brooklyn, Polytechnical Institute of: G. B. Hoadley

California Institute of Technology: S. S. Mackeown
California, University of: L. J. Black
Carleton College: Appointment Later
Carnegie Institute of Technology: E. M. Williams
Case School of Applied Science: P. L. Hoover
Cincinnati, University of: W. C. Osterbrock
Colorado, University of: Appointment Later
Columbia University: J. R. Raggazzini
Connecticut, University of: F. P. Fischer
Cooper Union: J. B. Sherman
Cornell University: True McLean

Detroit, University of: Appointment Later
Drexel Institute of Technology: Appointment Later
Duke University: W. J. Seeley

Florida, University of: P. H. Craig

Georgia School of Technology: M. A. Honnell

Harvard University: E. L. Chaffee

Idaho, University of: H. E. Hattrup
Illinois Institute of Technology: C. S. Roys
Illinois, University of: Appointment Later
Iowa, State University of: L. A. Ware

Johns Hopkins University: Ferdinand Hamburger, Jr.

Kansas State College: Karl Martin
Kansas, University of: G. A. Richardson

Lawrence Institute of Technology: H. L. Byerlay
Leigh University: D. E. Mode
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Maine, University of: W. J. Creamer, Jr.
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New York University: Philip Greenstein
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North Dakota, University of: C. W. Rook
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Northwestern University: R. E. Beam
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Oregon State College: A. L. Albert

Pennsylvania State College: G. L. Crossley
Pennsylvania, University of: C. C. Chambers
Pittsburgh, University of: L. E. Williams
Princeton University: J. G. Barry
Purdue University: R. P. Siskind

Queen's University: H. H. Stewart

Rensselaer Polytechnic Institute: H. D. Harris
Rice Institute: M. V. McEnany
Rose Polytechnic Institute: Appointment Later
Rutgers University: J. L. Potter

Southern Methodist University: H. J. Smith
Stanford University: Karl Spangenberg
Stevens Institute of Technology: F. C. Stockwell

Texas, University of: E. W. Hamlin
Toronto, University of: R. G. Anthes
Tufts College: A. H. Howell

Union College: F. W. Grover
United States Military Academy: P. M. Honnell
United States Naval Academy: G. R. Giet
Utah, University of: O. C. Haycock

Virginia, University of: L. R. Quarles
Virginia Polytechnic Institute: R. R. Wright

Washington, University of: A. V. Eastman
Washington University: Stanley Van Wambeck
Wayne University: G. W. Carter
Western Ontario, University of: G. A. Woonton
West Virginia University: R. C. Colwell
Wisconsin, University of: Glenn Koehler
Worcester Polytechnic Institute: H. H. Newell

Yale University: H. M. Turner

Institute Representatives on Other Bodies—1946

American Documentation Institute: J. H. Dellinger
ASA Standards Council: Alfred N. Goldsmith (R. F. Guy, alternate)
ASA Sectional Committee on Letter Symbols and Abbreviations for Science and Engineering: H. M. Turner
ASA Subcommittee on Letter Symbols for Radio Use: H. M. Turner
ASA Sectional Committee on National Electrical Safety Code, Subcommittee on Article 810, Radio Broadcast Reception Equipment: E. T. Dickey (Virgil M. Graham, alternate)
ASA Sectional Committee on Preferred Numbers: A. F. Van Dyck
ASA Sectional Committee on Radio: Alfred N. Goldsmith, chairman; Haraden Pratt, and L. E. Whittemore
ASA Sectional Committee on Radio-Electrical Co-ordination: J. V. L. Hogan, C. M. Jansky, Jr., and L. E. Whittemore
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ASA Electrical Standards Committee: H. M. Turner (H. P. Westman, alternate)
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ASA Sectional Committee on Graphical Symbols and Abbreviations for Use on Drawings: Austin Bailey (H. P. Westman, alternate)
ASA Subcommittee on Communication Symbols: H. M. Turner
ASA Sectional Committee on Specifications for Dry Cells and Batteries: H. M. Turner
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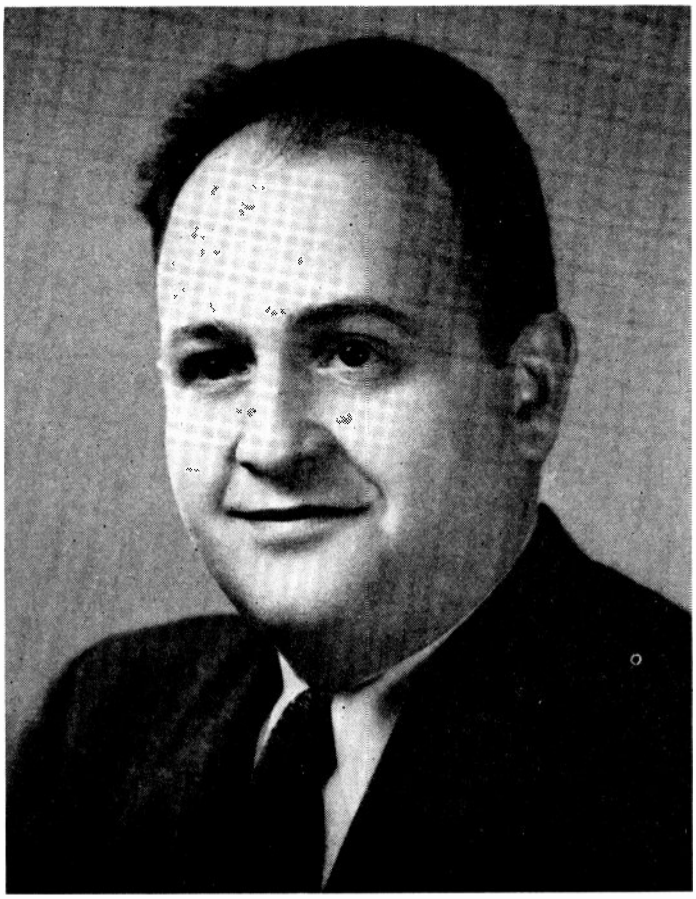
ASA Committee on Vacuum Tubes for Industrial Purposes: B. E. Shackelford
ASA War Committee on Radio: Alfred N. Goldsmith*
ASA War Standards Committee on Methods of Measuring Radio Noise: C. J. Franks and Garrard Mountjoy
Council of the American Association for the Advancement of Science: J. C. Jensen
Joint Co-ordination Committee on Radio Reception of the E.E.I., N.E.M.A., and R.M.A.: C. E. Brigham
National Research Council, Division of Engineering and Research: F. E. Terman
Radio Technical Planning Board: W. L. Barrow (D. B. Sinclair, alternate)
U. R. S. I. (International Scientific Radio Union) Executive Committee: C. M. Jansky, Jr.
U. S. National Committee, Advisers on Electrical Measuring Instruments: Melville Eastham and H. L. Olesen
U. S. National Committee, Advisers on Symbols: L. E. Whittemore and J. W. Horton
U. S. National Committee of the International Electrotechnical Commission: H. M. Turner

* Also chairman of its Subcommittee on Insulating Material Specifications for the Military Services.



Joseph General

Secretary-Treasurer, Dayton Section, 1946

Joseph General was born in Waltham, Massachusetts, on March 12, 1910. He was graduated from the Rindge Technical School in 1928 and attended Tufts College Engineering School and was graduated with the degree of Bachelor of Science in electrical engineering in 1932.

He was associated with Dr. G. W. Kenrick in Kennelly-Heaviside layer investigations; the relation between radio-transmission path and magnetic-storm effects; and the location of tropical storms using Watson Watt cathode-ray direction-finding equipment at Tufts College and at RCA Communications, Riverhead, and Rio Piedras, Puerto Rico, from 1931 to 1937.

He has worked with the Massachusetts State Police on two-way radio communication, and for the past six years has been engineer in charge of the radio and radar branch, Flight Test Division, Patterson Field, Ohio.

Mr. General is the recipient of a War Department Meritorious Award, signed by General H. H. Arnold, Commanding General, Army Air Forces, for services rendered to the Army Air Forces, and for his publication of a maintenance manual entitled "Maintenance of Signal Corps Aircraft Equipment."

He joined the Institute of Radio Engineers as an Associate in 1936 and was transferred to Member Grade in 1945. He has served as Secretary-Treasurer of the Dayton Section for the past two years and was one of the original group that founded the Dayton Section.

WAVES AND ELECTRONS has invited the Editors of journals in the radio-and-electronic domain to present to its readers their opinions and counsel which, being based on wide experience and detailed knowledge of the field, are of guiding value to engineers. There thus follows a guest editorial by the Editor of *Electrical Communication*.—*The Editor.*

The Engineer and Social Co-ordination

H. T. KOHLHAAS

This postwar "peacetime" world being greatly muddled, an editor is tempted to pose the question, "Why, instead of the world going round, does it not go ahead?" Briefly, I am convinced that what this country needs more than ever is neither a five-cent cigar, nor propaganda, but the comprehensive formulation and wide dissemination of blunt, unadulterated, basic facts and principles pertaining to our democracy and its functioning.

In London, in 1939, I was told that the Germans planned to train specialists in social co-ordination —individuals qualified to cope with over-all technical, political, and social conditions. In the United States of America this need perhaps also is gaining recognition—note the stress being placed by certain educators on training of our best minds in the social sciences. Einstein, it may be recalled, remarked some years ago that what this country needs most is leadership.

Too often political leaders are impelled to formulate policies after only superficial analysis and sell them to the people on an emotional basis. The consequence is that policies, laws, and commission decisions are too apt to be in conflict with the long-range interests of the country.

Many examples of the resulting lack of grasp of basic facts might be cited. Two should suffice: (1) During the war, perhaps properly, we referred to the Japanese "sneak" attack on Pearl Harbor. Does not history reveal plainly that a sudden attack somewhere was to be expected? (2) An item in the *New York Times* of January 25, 1946, "Some GI's Justify German Attack; Army Poll Shows Little Hostility," stated in part, "Authorities declared it (the survey) revealed an amazing lack of knowledge of the causes of the war, and that it appeared to indicate that the United States soldier in some cases had fallen for the propaganda of Germans echoing Joseph Goebbels." What else can one expect in this most complex age, when even election campaigns for high government office are conducted along emotional rather than factual lines?

Pre-1914, when a national crisis arose, the country looked to a prominent banker or industrialist for leadership, not always unbiased. Subsequently, high government officials assumed leadership, also not always unbiased, and now the labor leader is coming into greater prominence. But labor leadership too is not always wise from the viewpoint of the best interests of labor and the country.

Foreigners sometimes remark that we Americans are smug and not as good as we think we are. Heartsearching on the part of all of us without exception is urgently needed. Surely smugness or self-satisfaction is incompatible with progress.

People today, millions of them, crave enlightenment—unbiased, basic facts presented so that all can understand. A Committee or Board, if such were established, composed of outstanding individuals of the broadest viewpoint, could function as an educational or enlightening agency to acquaint the public with the fundamentals underlying many of our problems. Thereafter, solutions should become easier.

The Committee's basic thesis would be that this nation is fundamentally a democracy, devoted to the welfare of all, regardless of class, race, or creed. It would study basic social, industrial, agricultural, labor, educational, and governmental problems broadly and impartially, and point the way towards long-range constructive policies.

I am not advocating that The Institute take the lead in such an undertaking but rather that its members, and others, give consideration to implementing and participating in a movement in this direction. We Americans did an outstanding war job because we pulled together. We should be able to handle our peacetime job equally well, provided we formulate our objectives realistically, understand their implications, and adhere to them steadfastly.

One may confidently expect that the accomplishments of wartime technology will find many and useful applications in the arts of peace. Since World War II was pre-eminent among wars in its engineering achievements, it is natural to anticipate that its peacetime contributions may also be outstanding. Readers of the I.R.E. journal will accordingly find much of interest in the following guest editorial prepared by a scientific executive who is, as well, a Major General in the United States Signal Corps.—*The Editor.*

Commercial Applications of Wartime Science

G. L. VAN DEUSEN

With the easing of security restrictions the extent and importance of the contributions of science to warfare in radar, communications, and related electronic fields have been disclosed to the public. We can now foresee the early and widespread application of these new techniques to the needs of commerce and industry.

Radar will undoubtedly be of outstanding value as a navigational aid to air- and seacraft. Ocean-going vessels equipped with surface-search radar will have continuous, positive indication of all shipping in the vicinity, as well as an accurate picture of near-by land masses, icebergs, and other physical hazards. These devices will be especially helpful in fog and other conditions of poor visibility. Radar beams will supplement or replace fixed lights as aids to navigation.

The position-finding system known as loran (long-range navigation), developed during the War, may be extended for use wherever an extremely accurate, but simple, means of determining the position of a ship or airplane is required.

By the use of radar commercial aircraft will be able to read their absolute, or actual, altitude above the ground and to receive timely warning when approaching mountains or other obstacles. The application of such information must be so automatic as to relieve the pilot or navigator of responsibility for interpretation and decision. Crashes in mountainous regions by planes which are off their course in bad weather should no longer be chargeable to lack of proper information concerning ground hazards.

Long-range early-warning radar, similar to the "microwave" sets developed in the latter stage of the War, may be used to detect the presence of storm centers and to track their progress. This will be especially helpful in plotting storm movements over ocean areas.

"Radio relay" made possible the linking of higher military headquarters during landing operations and in periods of rapid movement such as followed the Normandy breakthrough. Here radar frequencies and transmitting techniques have been adapted to radiotelephony and -telegraphy, opening a new vista of multiple-channel communications in the ultra- and super-high-frequency bands. Improved equipment for automatic transmission and reception of radio-record traffic has also contributed to the integration of long-distance wire and radio systems, facilitating the establishment of world-wide communication networks.

Standardization of many components of electronic equipment was brought about during the War to simplify production and distribution problems, while giving proper weight to operating and maintenance conditions in the military service. These standards, subject to progressive revision, will now be available to industry as a guide wherever high quality is demanded.

Organized science, working in close co-operation with the technical services of the Army and Navy, achieved spectacular success in meeting the emergencies of World War II. There is now no reason why equally sensational advances should not be made in the corresponding activities of peace.

Some Broad Aspects of Specialization*

E. FINLEY CARTER†, FELLOW, I.R.E.

YOU MAY wonder why I have chosen this seemingly self-contradictory title for a discussion. How can breadth modify specialization? We think rightly of a specialist as one who has concentrated his efforts in the mastery of a chosen field for which he has developed certain outstanding talents. As such fields become broad, there is need for further specialization as has been evidenced over the years in other professions as well as in our own. Not so very long ago, a man specialized to become an engineer. Later, he had to choose whether he was to be a civil, a mechanical, or an electrical engineer. As the numbers of men engaged in these various branches grew, associations such as the American Society of Mechanical Engineers, the American Society of Civil Engineers, and the American Institute of Electrical Engineers were formed. It was only a little over thirty years ago that a few men with vision saw the trend of still further specialization and the Institute of Radio Engineers was organized. Even the most visionary of those men probably did not dream of two national conventions being held within the same week with three times as many registering for The Institute of Radio Engineers Winter Meeting as for the American Institute of Electrical Engineers Convention.

The fact that most of us who have engineering degrees received them in electrical engineering only serves to show that the trend toward specialization is so rapid that our basic training includes many things we soon discard and forget in order that we may concentrate our attention on our special interests and assignments. We accept the adage, "Jack of all trades; master of none," first as a warning of what might befall us if we do not become specialists, and then as a justification for letting our interest become so narrow as to exclude some that we can ill-afford to lose. Our profession becomes increasingly more complex as fields such as communications and industrial electronics broaden and become broken down into a great multiplicity of subdivisions which, in turn, are further divided so that a man can devote his full time to the study and mastery of a single phenomenon associated with the functioning of a vacuum tube, or in the study and application of a small portion of the frequency spectrum. Can you imagine the "International Society of Emission Engineers," or the "World Association for the Exploration of X Band"?

What we have seen in our profession can be witnessed in other professions, as well as in the world at large. I have heard my father say that his mother spun the cotton, wove the cloth, and made all the clothes for a big family, along with her other household duties. The family was not wholly, but almost, independent of the world in general insofar as their daily needs were concerned, but they were dependent upon one another. To some fell the responsibility of sowing, cultivating, and harvesting; to others, the chores of preparing, applying, and maintaining. Life was rugged and required much sweat and hard work, if less suspense and frustration. Relatively, no doubt, life seemed as complex then as it does today, and even within the small group that composed a large family, there were difficulties experienced in understanding each other and in fully recognizing this interdependence.

Why is it that in our search for knowledge we have explored the infinite and the infinitesimal—we can predict the courses of stars and planets in their orbits so accurately as to set the time and place of an eclipse a hundred years from now, or with the building blocks of the universe can construct elements not previously found in nature—and yet we still seem to be unable to answer the simple question asked by Cain, "Am I my brother's keeper?" We have learned to understand extremely complex mathematical equations and to make intricate and complex mechanisms whose performance is so easily predictable and whose operation is so simple that they are made to serve millions. But what have we done or what are we doing to understand the users of our creations?

I have been giving a great deal of thought recently to world events and have been wondering just why we have run afoul of many of these disturbances we have been seeing about us—seeking, as it were, the missing ingredient, the common solvent, or better, perhaps, the binder so sorely needed to hold civilization together harmoniously. I am convinced that this is a problem that may respond to the curious, analytical, and logical approach used by the engineer and scientist in solving other problems which, at least, at the first blush, seemed far more difficult of solution. I am likewise convinced that if enough engineers could get interested in a problem of this sort to make it a topic of general discussion and argument as free from prejudice and bias as some of our technical discussions, the results would be surprising. Let's start now on one facet of this problem. There are many, but let us consider the question of specialization and its part in the social picture.

Are our social problems today the result of overspecialization? Something seems wrong when 3500 tugboat operators can, within a week, paralyze the whole city of New York, or when a similarly small number of utility operators can tie up a city like Pittsburgh. What have we gained by making life so complex? Have we as individuals been short-sighted, or have we become narrow because we have concentrated our efforts on the

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† Sylvania Electric Products, Incorporated, New York, N. Y.

development of only a few talents? Wouldn't we be happier if we were more self-sufficient and less dependent upon people whom we do not know and have never seen? These questions are academic, for we are faced with the facts as they are; yet, they may help to stimulate sound thinking relative to what, if anything, we are going to do about it.

What should we do about it? Let us be logical and not overemotional as we explore this question. How are we going to recoup the security that we have lost through our specialization? Should we do as we find many others doing and form monopolies of our specialties so as to give us strong trading positions? In that way, we can at least make it hard on the other fellow if we don't get our just due. He will have to deliver, or else. That is, if he can deliver. If he can't, we all suffer—or do we all suffer anyway? Can there be economic gain by destroying wealth or by refusing to create it? Can we build a better society by refusing co-operation or by giving it?

I am afraid that a logical analysis of this problem would not yield the form of solution so generally tried. We do not offset the narrowness associated with specialization by a further withdrawal from society, nor do we enlist the aid and understanding of others through isolation. We may inflate our egos by criticizing those we do not understand, but we do not improve our stature by so doing, nor do we help others to understand us by being overly sensitive to and resentful of their criticism.

There can be little doubt but that specialization has brought with it many material blessings. Without it, who would be able to own a modern motor car or radio or television set, and if he owned it, what would he do with it? Our problem is not one of overspecialization; it is one of having failed to see some of the broader aspects of specialization, for corollary to specialization is understanding and co-operation within the complete social structure. There is no stronger team on the gridiron or in a business than a truly complementary group of individuals, each with his own particular talents. Let them pool this interest for the common good and they make a winning team; but let them become prima donnas, each seeking individual glory, and at best, it is a sad mess. Why does human society refuse to see that which should be so obvious? Why do so many individual members of society refuse to learn by experience? A newspaper survey, made some time ago, made the startling disclosure that only 5 per cent of the people think. Ten per cent think they think, and 85 per cent want someone else to do their thinking for them. I am convinced that among engineers, the percentage of those who think is much higher than 5 per cent. Because of this, I sincerely feel that as individuals, as well as an association of engineers, we can make a real contribution to the solution of our social ills by complementing our specialized talents with a sincere interest in the welfare of our fellow men. That interest can be the common binder which will weld humanity harmoniously together, for through it we shall learn to harness invisible, yet nevertheless real, forces such as understanding, confidence, faith, love, and tolerance just as we have those of electricity, gravity, and magnetism in the realm of the physical sciences. We do not fear that which we understand, nor those whom we truly know. Self-confidence is essential to a sense of security, and confidence in others gives strength to that much-to-be-desired feeling. Faith in oneself, in others, and in a worthy cause is a force whose power we should recognize and upon which we should capitalize. Similarly, participation is the healthy psychological prescription to develop the whole man who, in turn, tends to find the greater success in his specialized work. Tolerance and a love of one's fellow man has a binding power that, if applied, would hold the world together in a unity strong enough to negate those divisive forces which thrust themselves so rudely upon us today. With this unity, a state of balance could be established that would permit the full blooming forth of those great constructive forces locked within man only by his ignorance of himself.

The house referred to in the adage, "A house divided against itself cannot stand," has now become the world. Scientists and engineers, more than any other group, have brought this about, and among the leaders in this group have been radio and communication engineers. We have worked hard to make it possible for any man's voice to reach the ears of all others. I think it should concern us whether the facilities making this possible are used to disseminate truth and understanding, or whether they are used to sow suspicion or to propagate lies and misunderstanding.

I do not want to oversimplify the social problems that are before us today. On the other hand, I am afraid there are many capable of making real contributions in this field who are not doing so because they feel the problem is too complex, or is beyond their control. Let me remind those who entertain such thoughts that before they were able to understand alternating currents and resonant phenomena, they first learned a few principles about direct current, then mastered Ohm's Law, after which they continued until they were able to observe new principles and apply them effectively.

There is an Ohm's law for our social relationships. There are resistances to overcome, potential required to overcome them, and currents that can be put into action as these resistances are overcome. There are also inductive and capacitive components in human society; each of you has encountered leading and lagging reactances. When we start to deal in human emotions, we get into resonant phenomena which are seemingly more complex and less predictable than those we have encountered in the field of radio engineering, but perhaps they would not be actually so if they were approached as analytically and as logically as we approach the problems within our special fields.

I am not urging anyone to shift from his chosen field of, let us say, radio engineering to that of psychology, even though by so doing he may carry over certain techniques which would help him in his new field. What I am urging is that, along with our specialization, we develop broad interests which will not only help us to realize our interdependence, but will also awaken us to our social responsibilities and to a desire for a still broader understanding of the one science in which we should all want to specialize; namely, the science of living.

It is important for us to remember that, though we have set ourselves apart as members of a specialized profession, we continue as members of the great brotherhood of humanity. We still bear on our shoulders the heavy responsibilities that such membership carries with it.

First, of course, nearly all of us have inescapable duties as members or heads of families. Those who are parents share in the vitally important task of passing on to the next generation not only love, but the high points of the knowledge of life that we have gained in our own experience. Too often, we have seen the examples of men who are successful in business but low in competence as parents. This has been one of the basic causes of the commonly accepted tradition of "shirtsleeves to shirtsleeves in three generations."

Modern professional and business life takes us away from our homes, so that special effort may be required. Here science and production have made one contribution through the development of the five-day week, which permits us two full days for relaxation and close, personal contact with those in whom we have the most immediate interest.

I think it is in order to mention here that many of us are also members, albeit perhaps not so active as we might be, of some church group. Clearly, many of our ills in the world today can be solved only with a resurgence of spiritual morale and re-emphasis on the brotherhood of man and the age-old principles of successful living together.

The art of living together is also controlled in large measure by our methods of government and the men whom we select to govern. A third nonspecialized responsibility of each of us, therefore, becomes that of the responsibility of the citizen. Under our American form of government, our political structure rises from the people. In Revolutionary days, only a relatively small proportion held the franchise. These tended to be those who were the more wealthy or more able. As the franchise has been extended to include today, at least in theory, almost the entire adult population, those who are gifted with exceptional ability or have had unusual educational, professional or business opportunities, therefore have the increasing responsibility of making their full contribution to the political life of our country. For them to withdraw from politics means to leave one of the most vital functions of our people in the hands of less-competent individuals with results that are often far too evident.

We need not be discouraged by the extent of the problem of being what might be called "all-around citizens." There are more than enough examples in our history and in current life today of men who have been outstanding in their professional attainments and who have maintained the same high level of excellence in their contributions to family, religious, and civic life. Indeed, the members of the group are particularly fortunate. We should be able to bring a scientific viewpoint tempered in the crucible of years of difficult work and scientific study to the solution of our problems. By the development of greater understanding and love for our fellows, we can help to make still more effective our personal contributions within our own groups. The impartial, truth-seeking approach of the engineer can be made into a tool of great value.

Each of us has an opportunity of unlimited research in this field. Each has an ever-present laboratory in which to experiment within himself. An earnest study of our behavior patterns and reactions to outside stimuli, followed by an objective application of the findings to our relationships with others, should enable us to make real contributions to the solutions of many common problems.

In closing, I would like to leave with you the challenge to utilize these facilities for observation and analysis of human reactions to the utmost, in order that you may make your specialized efforts a part of a broad plan of living from which you and all society will benefit.

Television Equipment for Guided Missiles*

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LEONHARD KATZ‡, MEMBER, I.R.E.

Summary—**A brief history of the technical problems associated with the development of compact airborne television equipment is outlined. The system provides resolution, linearity, and stability which approaches that obtained from broadcast equipment. Technical difficulties which arose after the completion of the equipment design are described. The final solution of these and other problems resulting from its installation in guided missiles are discussed. Photographs taken from the receiver screen during experimental flights are shown.**

INTRODUCTION

WITH THE rapid growth of the electronic art, during the latter part of the past decade, there appeared a definite possibility of utilizing television equipment in "suicide-type" airborne missiles in order to achieve high accuracy. Consequently, a project was established by the Army Air Forces for the development of television equipment for use in guided missiles of the direct-controlled type. It became the task of the Signal Corps Aircraft Radio Laboratory to develop equipment to meet these needs.

As a result of a development project involving television for another application, the RCA-Victor Division of RCA redesigned their portable equipment as an experimental model[1] called "jeep," for the preliminary tests.

Fig. 1 illustrates the essential airborne equipment, whose installed weight, including cables, antenna, brackets, etc., was 340 pounds. Its power demand from the airplane power supply was 45 amperes at 28.5 volts. During the course of the execution of this engineering problem, thought quite naturally evolved around the use of television for guided missiles. Sufficient interest was shown by the military authorities and the result was the construction of an experimental model which was called "jeepette" by the RCA engineers because of its ancestry.

Numerous flight tests at Wright Field with the "jeep" design had shown that compact, lightweight television equipment could be developed and used in aircraft. The problem of multiple paths of the radio-frequency energy from the transmitter to the receiver did not appear as a serious difficulty and neither did the somewhat lower than broadcast quality of the received picture. Since immediate application of the equipment was deemed advisable, development work on the "jeepette" was pushed. During April, 1941, tests were conducted with this equipment installed in a B-18A airplane; however, without a radio link. It was necessary to determine the practicability of television as an adjunct to radio remote-control equipment for guided missiles. The camera was located in the nose of the airplane on the bombsight mount, while the monitor was located in the "blacked-out" rear compartment. From an altitude of 5000 feet and at a distance of five miles, it was possible to guide the plane on a collision course by means of observing the television monitor and calling course corrections to the pilot of the airplane over the interphone system. The result of these tests was the establishment of a development contract with the RCA-Victor Division of the Radio Corporation of America.

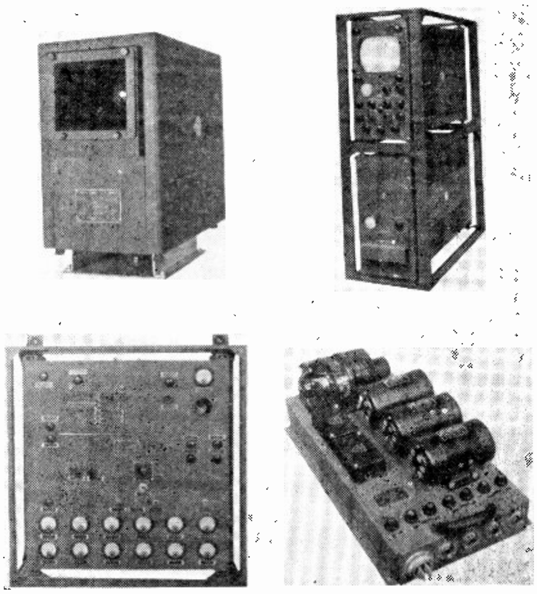

Fig. 1—625-line airborne television transmitting equipment known as "jeep." Upper left, camera; upper right, camera control and auxiliary units; lower left, radio transmitter; and lower right, dynamotor power supply.

Small size and weight immediately dictated that compromise television system standards must prevail. As a result of an analysis of the problem, it was decided to adhere to commercial or broadcast standards as much as possible. The following compromise standards were adopted at that time:

1. Forty frames per second.
2. 350 lines per frame.
3. Sequential scanning.
4. Video bandwidth of 4.5 megacycles.
5. Vertical polarization of radiated signal.
6. No direct-current transmission.
7. Omission of equalizing pulses.
8. Omission of serration of vertical-synchronizing pulse.

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[1] G. L. Beers, O. H. Schade, and R. E. Shelby, "The RCA portable television pickup equipment," PROC. I.R.E., vol. 28, pp. 450–458; October, 1940.

(9) Synchronizing signal equal to approximately 35 per cent of carrier.

(10) Double-sideband transmission.

(11) Wider than Radio Manufacturers Association standard vertical-blanking and synchronizing pulses.

(12) Wider than Radio Manufacturers Association standard horizontal-blanking and synchronizing pulses.

The military standards were chosen after consideration was given to the size, weight, power demand, circuit complexity, resolution, and linearity interrelationships. It must be remembered that the tube complement was "frozen" in 1942 and at that time miniature tubes were not available. There are many technical papers which outline the considerations involved in choosing television standards.[2–11]

During the course of this development program, the possibilities of types of camera pickup tubes, other than the iconoscope, appeared worthwhile of investigation. In particular, a development model of an image-dissector camera and several cameras using pickup tubes having low-velocity scanning (such as "orthicon" and similar types) were tested. These tubes, however, were found to have little or no advantage over the iconoscope, and for military reasons were found to be inferior.

Development of 100-Megacycle Equipment

In the design of the first small television system, known as SCR-549-T1 and SCR-550-T1, the previously stated characteristics were embodied. It will be apparent from Fig. 2 that a considerable reduction in size and weight has been effected over that of the "jeep." The total weight of the transmitting equipment, installed in an airplane, was approximately 60 pounds, less monitor unit and 14-volt 7-cell storage battery, which weighed 20 and 37 pounds, respectively. As to performance, little difference between the two systems could be noticed, although the "jeep" operated at 20 frames, 40 fields and 625 lines, interlaced scanning. The technical problems were too numerous at that time so that interlacing did not appear as a practical solution for the scanning system because "pairing" was generally observed during most airborne operations.

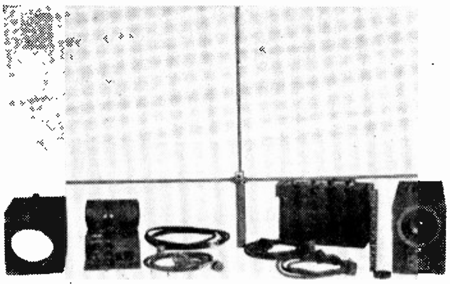

Fig. 2—Radio transmitting equipment SCR-549-T1. Left to right: transmitter monitor, dynamotor power supply, 100-megacycle antenna, 7-cell lead-acid storage battery, and camera-transmitter.

Reference is made to the block diagram, Fig. 3, where the synchronizing generator and shaping equipment customarily used in broadcasting studios have been replaced by three dual-triode vacuum tubes and associated circuits. This simplification was accomplished at the expense of a lower number of scanning lines, lack of interlacing, higher blanking intervals, lower synchronizing stability, but with reasonably good picture quality. The usual iconoscope deflection system has been replaced with just five vacuum tubes including their circuits. In addition, these few tubes perform keystone, shading, and high-voltage power-supply functions. The video amplifier is somewhat simplified by combining the iconoscope with the entire video amplifier. The transmitter occupies a small compartment in the rear of the camera-transmitter unit. A power output of approximately 15 watts at 100 megacycles is provided. The 6V6GT modulator is capable of providing 100 per cent modulation with a normal scene on the iconoscope mosaic.

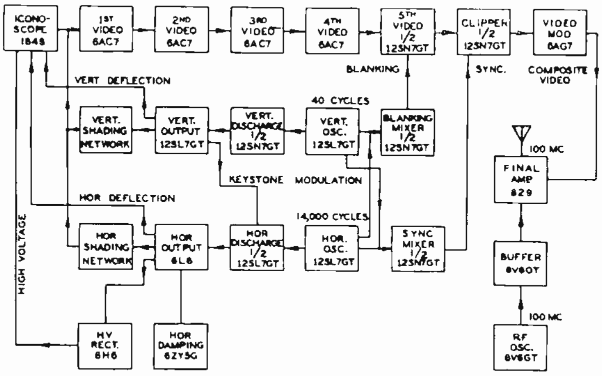

Fig. 3—Functional block diagram of 100-megacycle camera-transmitter.

This early equipment was capable of operating with as low an illumination as 200 foot-candles on a normal contrast scene; however, bias lighting was not used. The lens used was a Bausch and Lomb Tessar with a focal length of $8\frac{1}{4}$ inches and $f=3.5$. An RCA "Magicote" lens coating was used on the optical surfaces.

The horizontal- and vertical-timing pulses are generated in their respective multivibrator-type oscillators and are then coupled into a blanking mixer-amplifier. The composite blanking signal is then mixed with the

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[2] E. W. Engstrom, "Television image characteristics," Proc. I.R.E., vol. 21, pp. 1631–1650; December, 1933.

[3] E. W. Engstrom, "A study of television image characteristics," Proc. I.R.E., vol. 22, pp. 295–310; April, 1935.

[4] R. D. Kell, A. V. Bedford, and M. A. Trainer, "Scanning sequence and repetition rate of television images," Proc. I.R.E., vol. 24, pp. 559–576; April, 1936.

[5] V. K. Zworkyin, "Iconoscopes and kinescopes in television," *RCA Rev.*, vol. 1, pp. 60–84; July, 1936.

[6] S. W. Seely and C. N. Kimball, "Analysis and design of video amplifiers," *RCA Rev.* vol. 2, pp. 171–183; October, 1937.

[7] Albert Preisman, "Some notes on video amplifier design," *RCA Rev.*, vol. 2, pp. 421–432; April, 1938.

[8] A. V. Bedford, "A figure of merit for television performance," *RCA Rev.*, vol. 3, pp. 36–44; July, 1938.

[9] S. W. Seely and C. N. Kimball, "Analysis and design of video amplifiers," *RCA Rev.*, vol. 3, pp. 290–308; January, 1939.

[10] R. D. Kell, A. V. Bedford, and G. L. Fredendall, "A determination of optimum number of lines in a television system," *RCA Rev.*, vol. 5, pp. 8–30; July, 1940.

[11] D. E. Foster and J. A. Rankin, "Video output systems," *RCA Rev.*, vol. 5, pp. 409–438; April, 1941.

video signal in the plate circuit of the fifth video stage. The synchronizing signals are derived from the same oscillators and are mixed in an amplifier whose output is applied to the cathode of the cathode follower-clipper; thus synchronizing, blanking, and video have been combined to form a composite video signal which is coupled to the video amplifier and modulator of the transmitter section by means of a short length of coaxial cable. The video and synchronizing output signals for the transmitter monitor is also derived from the cathode-follower output terminal.

For deflection of the iconoscope beam, the horizontal and vertical frequency pulses are fed into discharge tubes and, thus, saw-tooth voltage waves are derived for use in driving the respective output tubes through coupling transformers to the deflection yoke. Output voltage from the vertical-deflection tube is used as the plate-voltage supply for the horizontal-discharge tube. This simple circuit provides excellent keystone modulation of the horizontal saw-tooth deflection voltage.

By means of an additional winding on the horizontal output transformer, high-voltage pulses are derived which are then rectified and filtered. This circuit provides approximately 1000 volts direct current for the iconoscope electron gun.

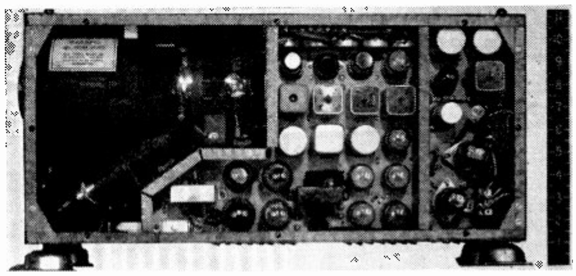

Fig. 4—Interior view of camera-transmitter of SCR-549-T2. All tubes except first video amplifier, high-voltage rectifier, and final amplifier are shown.

Single and double integration of the deflection voltages on the secondary of the output transformers results in parabolic and saw-tooth shading voltages at line and frame frequencies. These resulting voltages, which are capable of 180-degree phase variation, provide good shading-signal corrections under all operating conditions.

Since the number and size of the vacuum tubes used in the camera-transmitter unit (see Fig. 4) have been reduced drastically from those normally used, the power-supply dynamotor could be reduced to a very small value. The iconoscope heater power is supplied by a separate 6.3-volt section on the dynamotor. This section has been insulated for 1000 volts from ground, since the positive side of the iconoscope high-voltage system is at ground potential.

Simplifications which have been applied to the design of the camera-transmitter unit could not be applied, in general, to the receiver equipment, since the maximum possible sensitivity was needed in order to complement the low radio-frequency transmitter power output. By judicious disposition of components it was possible to build a complete receiver, including the dynamotor power supply, into one case as illustrated in Figs. 5 and 6. The cathode-ray picture-tube type 7CP1 was chosen in preference to the type 7AP4, because the green screen provided a picture of better contrast under high ambient light conditions. A green-light filter, placed in front of the screen, could be used to further attenuate the effects of the external stray light.

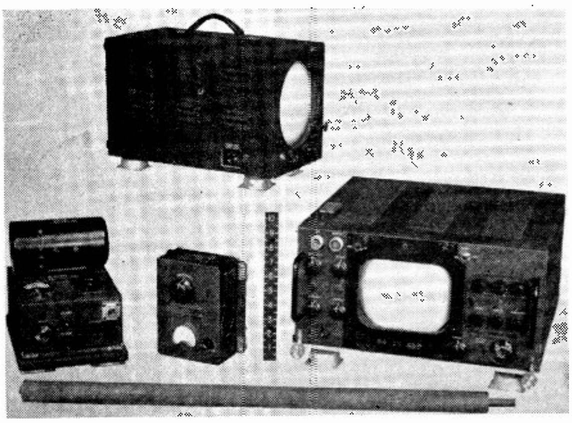

Fig. 5—Receiving equipment SCR-550-T2. Top: receiver monitor; bottom row: monitor power supply, receiver-voltage-control box, receiver, and 100-megacycle "bazooka" just below.

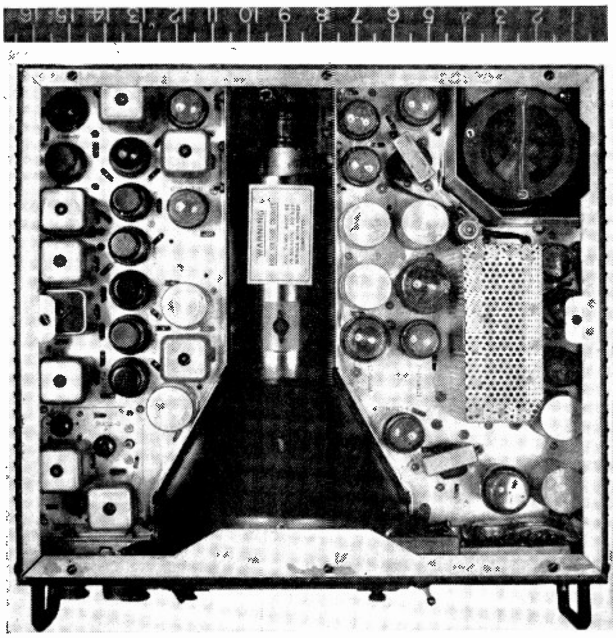

Fig. 6—Receiver of SCR-500-T2 showing radio-frequency, intermediate-frequency, and video amplifiers on the left side; deflection system, high-voltage power supply, and dynamotor on the right side.

For adjusting the performance of the camera-transmitter and for providing an additional picture at the receiving point, a monitor unit, as shown in Figs. 2 and 5, was designed.

Power is derived from the camera-transmitter when the monitor power plug is inserted into the rear of the unit. This automatically transfers power from the transmitter to the monitor.

The transmitter monitor is somewhat different from the receiver monitor in that hold controls are incorporated. It was inconvenient to change the camera-transmitter units in order to use a directly driven monitor.

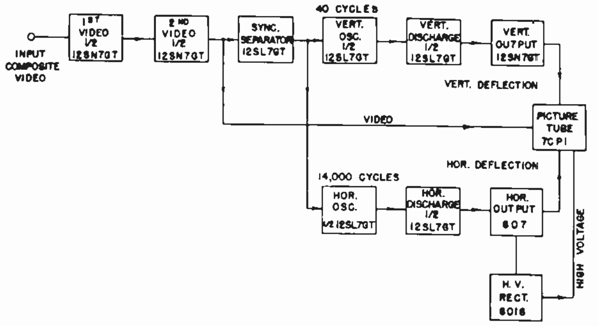

Fig. 7—Functional block diagram of monitor for 100-megacycle camera-transmitter.

Referring to the block diagram of the receiver, Fig. 8, it can be seen that the converter and intermediate-frequency portions of this receiver are in accordance with standard practice. The detector is coupled to the limiter through a video peaking circuit. The circuit of the limiter is arranged to clip noise pulses to a value slightly in excess of the synchronizing pulses. The limiter prevents the passage of noise-pulse amplitudes which would tend to override the synchronizing pulses.

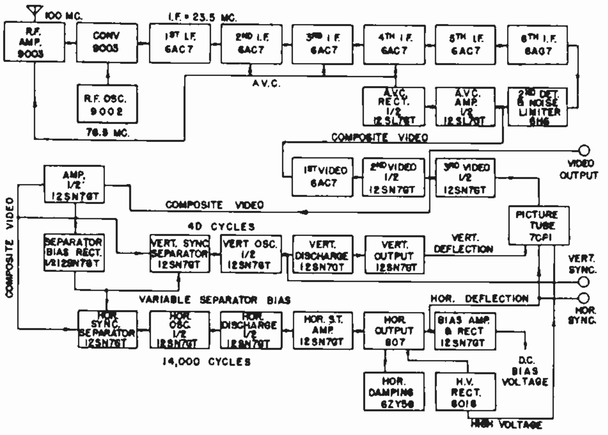

Fig. 8—Functional block diagram of 100-megacycle receiver.

The composite video signal from the limiter is then amplified and used to modulate the grid of the 7CP1 picture tube. It is unnecessary to eliminate the synchronizing pulses from the video and blanking signals, because these pulses drive the grid into the infrablack region of its grid characteristic and, thus, are not harmful to the picture.

Part of the composite video signal is amplified by an amplifier whose high-frequency response is just sufficient to pass the synchronizing signals. Three paths are provided for the output signal. One has a low-pass resistance-capacitance filter for passing only the vertical-synchronizing pulses. The second has a resistance-capacitance filter for passing only the horizontal-synchronizing pulses. The third path provides a signal to a rectifier whose direct-current output is used to bias the separator tubes in proportion to the signal strength. By this means any vestige of the video component is removed and the synchronizing-signal amplitudes are held within reasonable limits. The synchronizing pulses are then used to "lockin" the blocking oscillators to achieve synchronization. The remainder of the synchronizing circuits are conventional with the exception of the high-voltage power supply for the 7CP1. Approximately 4200 volts is obtained from the rectified "kickback" pulse and to this is added the 300 volts from the dynamotor. Consequently, a total of 4500 volts is available for the picture tube. Filtering of the ripple voltage is rather simple because of the relatively high frequency of 14,000 cycles.

The automatic-volume-control system in the receiver is not in accordance with standard practice. In particular, the automatic-volume-control rectifier and amplifier operate on the video voltage, rather than on the intermediate-frequency signal. Thus, compensation is made for the variation in light level and percentage modulation at the transmitter. Another feature of the automatic-volume-control system which deserves special mention is its low time constant. In airplane-to-airplane transmissions, rarely does the field strength at the receiver remain reasonably constant. On the contrary, it fluctuates widely from zero to maximum at a rather rapid and unpredictable rate. The automatic-volume-control system must be capable of following these variations. Actually, the time constant was so low that the shape of the vertical-synchronizing pulses was affected. Compensation for this effect was made in the vertical-synchronizing separator.

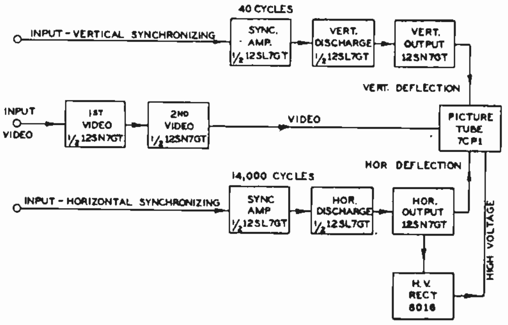

Fig. 9—Functional block diagram of monitor for 100-megacycle receiver.

The receiver monitor is in accordance with conventional design, as can be seen from Figs. 5 and 9. Horizontal- and vertical-synchronizing pulses are obtained from the receiver and are used to drive discharge tubes directly; therefore, the bothersome hold controls are eliminated. The remainder of the monitor circuit is similar to its counterpart in the receiver. Power for this monitor is obtained from a separate dynamotor power unit.

During the experimental testing of the T1 equipment, it became apparent that an insufficient number of units was available to continue the test work efficiently. An additional quantity of 100-megacycle transmitters and receivers, designated SCR-549-T2 (see Fig. 10) and SCR-550-T2 (see Fig. 5), were procured. They differed very little from the T1 equipment as to external appearance; however, there were many detail changes that were made in order to expedite production and to simplify installation. Further exposition of the details of these units would not add any worth-while technical data to this paper.

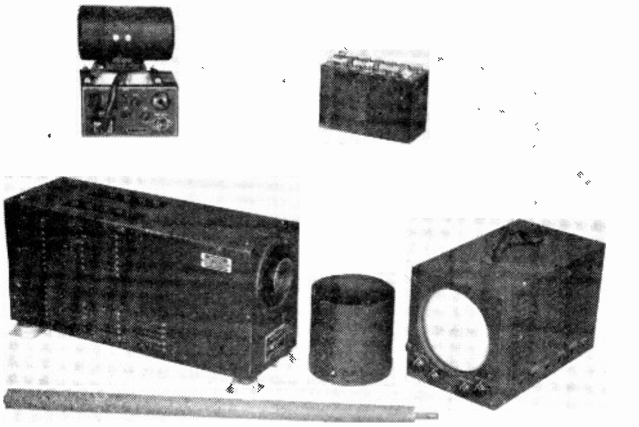

Fig. 10—Transmitting equipment SCR-549-T2. Left to right, upper row: dynamotor and junction box, 7-cell storage battery; lower row: camera-transmitter, transmitter monitor with light shield, and 100-megacycle "bazooka."

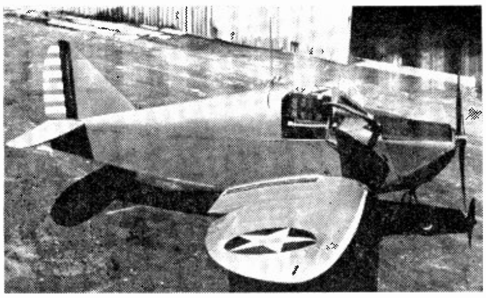

Fig. 11—PQ-8 target airplane with television camera-transmitter on right side in the cockpit.

Many minor circuit modifications were made at Wright Field in order to obtain satisfactory results under flight-test conditions. Several changes were necessary because of inexperience with the installation problems of television in small aircraft. Numerous others were due to unforeseen flight conditions on which there was no previous experience that could be called upon for guidance.

FIELD TESTS OF 100-MEGACYCLE EQUIPMENT

The T1 equipment was delivered early in 1942 and flight-test work began immediately at Wright Field. A B-23 airplane was equipped to carry either the transmitting or receiving equipment. A ground station in a half-ton truck was used for the other end of the television link and for maintaining radio communication with the B-23 airplane. The first results did not appear encouraging and a considerable number of experimental changes were made, some being retained as worthwhile and necessary, while others were immediately discarded. When results began to improve, a set of transmitting equipment was installed in a small PQ-8 target airplane, shown in Fig. 11, while the receiving equipment was installed in a B-23 airplane (see Fig. 12). Tests at both Eglin Field, Florida, and Wright Field, Dayton, Ohio, demonstrated that airborne television was practical but emphasized the need for equipment design utilizing the best quality of components and workmanship.

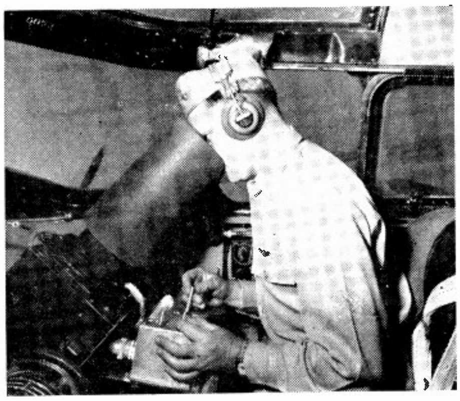

Fig. 12—Remote control pilot's installation in B-23 airplane.

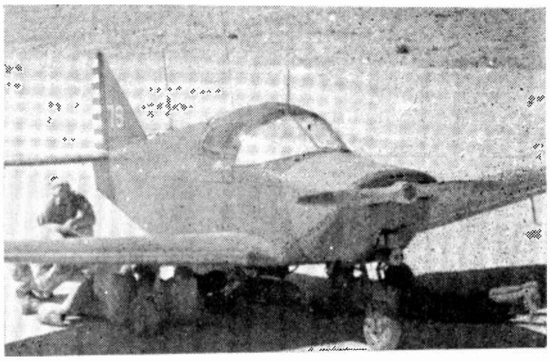

Fig. 13—100-pound practice bomb being suspended under PQ-8 target airplane. This plane was flown "nullo" by radio control. The television camera-transmitter was located on the left side in the cockpit.

Upon close examination of Fig. 11, it will be apparent that the television camera must look through the propeller disk. The light-reducing effect comes in the form of pulses, one pulse per blade. For typical small engines, the frequency generated is approximately 80 pulses per second, or two bars per frame. The engine is not usually in synchronism with the vertical oscillator, so that, if the pulse generated by the propeller just precedes the vertical-synchronizing pulse, synchronization of the receiver will be seriously disturbed. Since there were no plans to use small, single-engined aircraft as missiles, little effort was concentrated on finding an exact solution for this problem. A fair solution was found by reducing the low-frequency response of the video amplifier.

This was done by reducing the coupling capacitor between the fourth and fifth video stages to a low value such that the attenuation of the low frequencies extended to about 8000 cycles per second. (Fig. 19 shows a typical television scene in which the low frequencies have been reduced in amplitude.)

During the latter part of 1942, a complete PQ-8 radio-controlled target plane, similar to that in Fig. 13, was flown at simulated targets by means of the television picture transmitted back to the control airplane. This was one of the first airplanes to be flown "nullo" (pilotless airplanes flown from another airplane by means of radio remote control) with a television camera to aid in steering collision courses with fixed and moving targets. This airplane did not have adequate payload to be used as a missile.

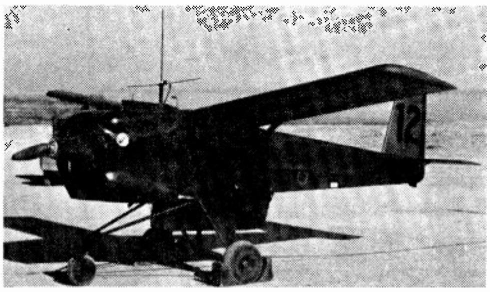

Fig. 14—General Motors "Bug" showing 100-megacycle television antenna on top of fuselage and nacelle containing camera-transmitter underneath.

During the month of May, 1943, tests were made at Muroc Lake, California, using the General Motors Bug as a guided missile. SCR-549-T2 transmitting equipment was installed in the Bug, while SCR-550-T2 receiving equipment was installed in a B-23 control airplane (see Fig. 12). In this particular installation, the television camera-transmitter unit was suspended beneath the fuselage of the Bug, housed in a streamlined nacelle, while the antenna was mounted on top of the Bug (see Fig. 14). The radio-control and flight servo equipment were mounted on the inside of the fuselage.

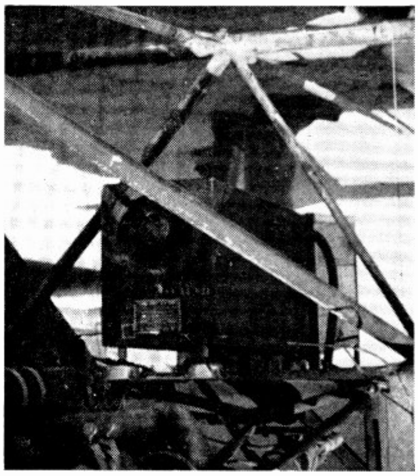

Fig. 15—100-megacycle television camera-transmitter suspended under General Motors Bug.

The location of the camera was such that a large part of the viewed scene was intersected by the path of the propeller (see Fig. 15). Although in this case the problems were not as serious as with the PQ-8 type aircraft, where the entire scene was viewed through a rotating propeller, there was a definite effect from the propeller resulting in the generation of low-frequency transients. A similar modification as that made in the case of the PQ-8 was made here; that is, a reduction in the amplifier gain at low frequencies.

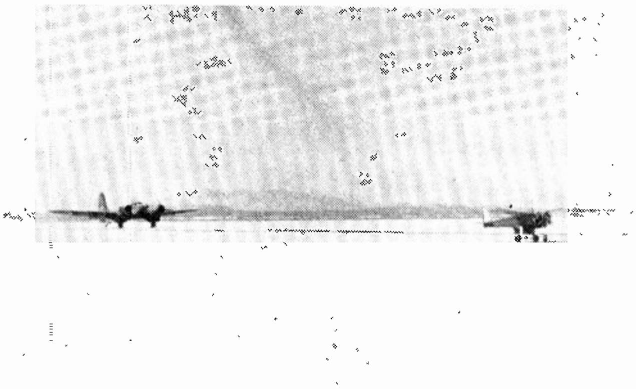

Fig. 16—General Motors Bug being taxied by radio control from B-23 airplane at Muroc Lake, California.

After all the necessary ground checks had been completed (see Fig. 16), the Bug was launched and a successful television picture was obtained during the whole flight. The Bug was finally dived into a target by radio control using television as a means of guidance.

An interesting feature which developed during the tests with the Bug was the determination of the angle between the line of flight of the missile and the line of sight of the camera. It must be realized that the angle of attack of an airplane wing will change with airspeed. Thus, the angle between the line of sight of the television camera and the line of flight of the missile will change. Also, the navigation of a guided missile towards the target area requires a steeper angle than the diving angle of the missile when on the final run. A compromise solution was finally agreed upon and proved to be very successful.

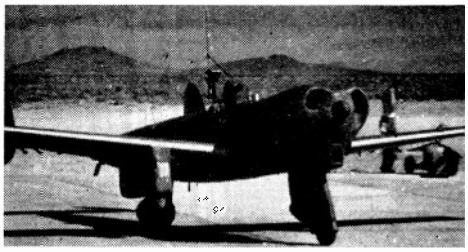

Fig. 17—YPQ-12A target airplane showing nacelle for camera-transmitter under right wing. In bomb position, a 500-pound bomb is placed in pilot's cockpit.

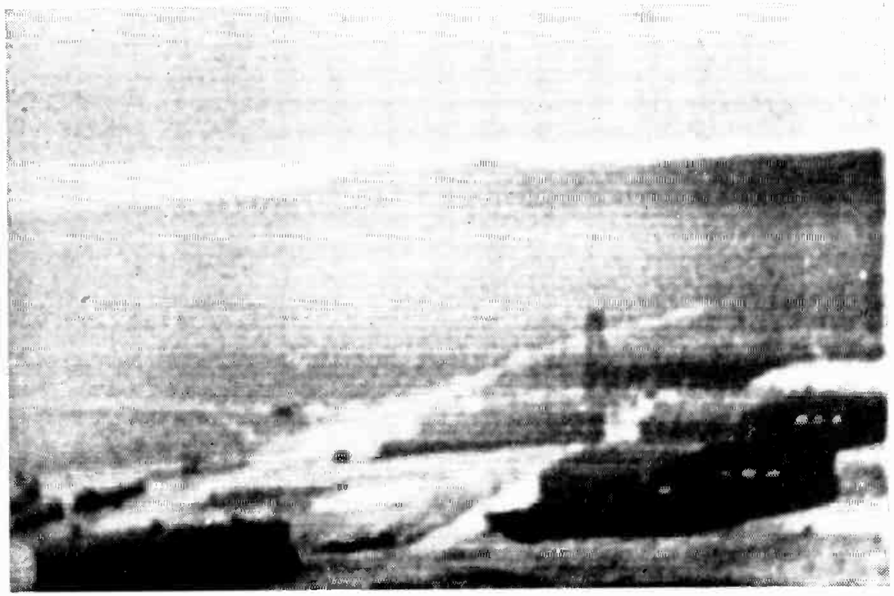

Fig. 18—Base area at Muroc Lake, California, showing fine streaking due to high-frequency microphonics and "highlighting" of mountain range in background due to loss of low frequencies. Photo taken from motion-picture sequence as recorded from 100-megacycle receiver.

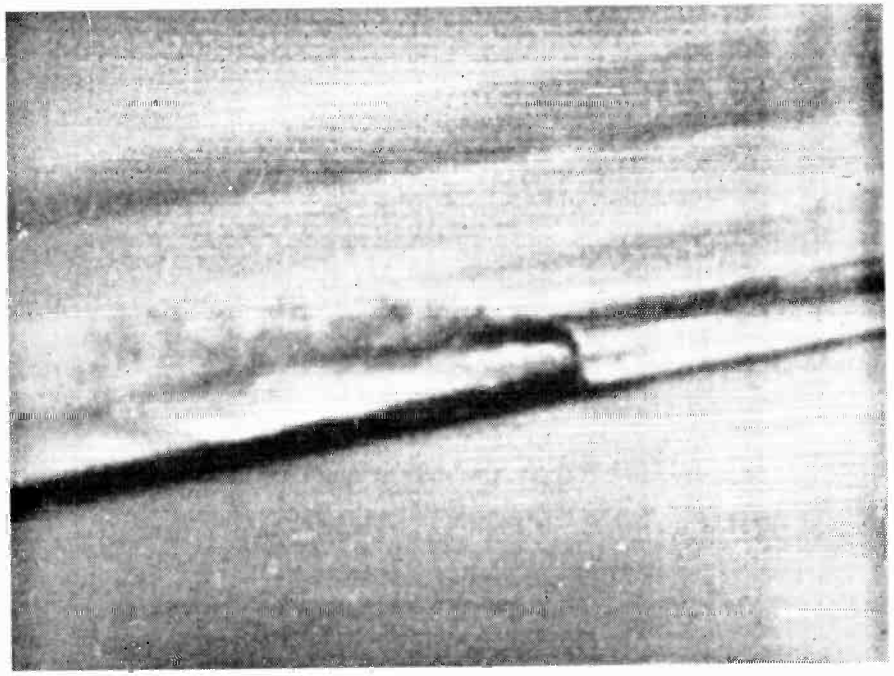

Fig. 19—Moving train as seen on television screen at Muroc Lake, California. Camera was located in YPQ-12A airplane making simulated attack.

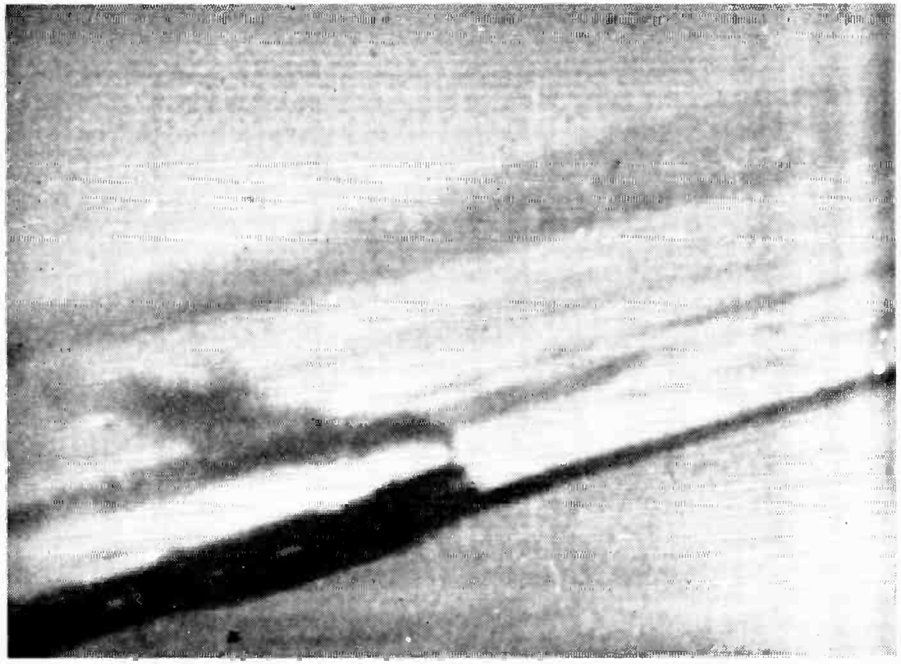

Fig. 20—Target of Fig. 19 a few moments later. Note the microphonics which reduce the resolution. White area in foreground is a dry lake bed, while the dark band in the background is an area of higher elevation.

Fig. 22—Dry-lake area at Muroc Lake, California, as seen by television camera in YPQ-12A. Monotony of landscape makes identification difficult.

The use of a television transmitter and a radio-control receiver operating in close proximity in the missile made special protection of the radio-control receiver imperative. Freedom from interference was obtained by the addition of a wave trap in the antenna circuit of the radio-control receiver. No interference was observed between the radio-control transmitter and the television receiver in the control airplane.

During August, 1943, it became apparent that all of the units of the power-driven bomb, that is, aircraft, power plant, flight servo, radio control, and television equipment, had been sufficiently developed to warrant a demonstration before interested military officials. Therefore, an expedition was dispatched to Muroc Lake, California, for the purpose of testing the military possibilities. In this case, SCR-549-T2 transmitting equipments were installed in YPQ-12A target airplanes to be used as power-driven bombs. The YPQ-12A airplane (see Fig. 17) was of the single-engine type, and therefore it was necessary to mount the television camera so that its line of vision would be outside the propeller arc. A nacelle for holding the camera-transmitter was mounted underneath the right wing of the airplane just outside the propeller disk. A lead weight was mounted on the left wing tip to counteract the unbalancing effect of the television camera on the right wing.

In spite of shock-mounting and acoustic treatment of the camera, the exhaust, propeller, and wind noises were so great (Fig. 23) that it was necessary to alter the low-frequency response such as to omit the fundamental frequencies of acoustic interference. The method used was the same as was previously outlined for use with the PQ-8 and the General Motors "Bug." Since it was not necessary to "look through" the propeller, the loss of low frequencies and the resultant increased phase shift were not as harmful to the final picture as might be supposed. In fact, from a military point of view the picture was improved, since the objects had a high light or contrasting border which aided in finding the target and in keeping the eyes fixed on it. See Figs. 18, 19, and 20.

During the preliminary tests, approximately 10 hours of flight were made in which a YPQ-12A was under direct radio remote control and during which the television picture was the sole source of information for the control pilot. The control airplanes were either an AT-7 or a B-23. Except for a vacuum-tube failure, the equipment gave no difficulty during the entire test program.

For the final or bomb run, a 500-pound bomb was placed in the safety pilot's cockpit and a hatch was used to cover the compartment. The television picture was adequate so that complete control over the missile could be maintained at all times. For its final run, the missile was controlled to a position directly behind a PQ-8 (Fig. 21) radio-controlled target and then exploded by means of the radio-control equipment. The television picture in the control plane was excellent, and it was possible to explode the bomb approximately 75 feet behind the target airplane. Later, on the same day, another YPQ-12A was flown into a ground target. Figs. 22 and 23 show the type of landscape at Muroc Lake, California. During this entire test program no new difficulties developed that had not already been discovered previously.

DEVELOPMENT OF 300-MEGACYCLE EQUIPMENT

As a result of the tests with the 100-megacycle equipment, it was demonstrated that light-weight television equipment was feasible for use in guided missiles. These sets, however, had a number of inherent limitations which made their use as military equipment undesirable. Therefore, it became necessary to formulate new specifications as to performance and operation.

The performance limitations which ruled out the further use of the 100-megacycle equipment in guided missiles can be summarized as follows:

1. The primary input voltage of the 100-megacycle equipment was 12.5 volts direct current. As this equipment was to be used in power-driven missiles having a 28-volt direct-current electrical system, it would be necessary to change the equipment for 28-volt operation.

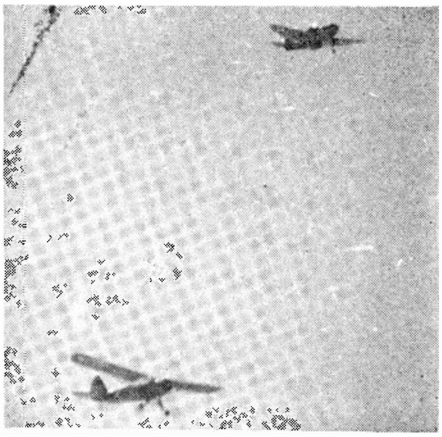

Fig. 21—PQ-8 target airplane under radio control from L-5 airplane underneath. This was just prior to assault by YPQ-12A airplane as power-driven bomb.

2. There was only one radio-frequency channel available and this located in a region of considerable interference. Tactical considerations necessitated the availability of additional channels to permit the simultaneous operation of several missiles.

3. Some of the radio-frequency energy was coupled from the transmitter section into the camera section. This was a result of the combination of transmitter and camera section into one chassis.

4. Excessive antenna size, which prohibited the use of this equipment in small missiles.

5. Equipment would not operate at high altitudes or under extreme conditions of temperature and humidity to be expected in military operations.

While a few of the 100-megacycle equipments had been built as experimental models to explore the possibilities of television in guided missiles, it was realized that quantity procurement could be anticipated.

If success is to be achieved in the design of equipment for expendable missiles, the philosophy of low cost has to be disregarded entirely. While missiles have no recoverable material, they must be extremely reliable. Since the cost of the television equipment (approximately 2000 dollars) represents only a small portion of the cost of the entire missile, especially in the case of the "war-weary" aircraft, savings are not justified if they result in unsuccessful missions. Therefore, it was emphasized that, although the equipment was expendable, design and production had to be according to standard Signal Corps requirements, which represented, closely, actual conditions that would be encountered in military use of airborne radio equipment. It was often necessary to make compromises in the interest of size and weight, in which cases deviations from the standard requirements were permitted. In making these deviations good judgment had to be applied, as the consequence of permitting the performance of an equipment to be limited by certain factors may be far reaching. For instance, in the beginning, when it was planned to fly guided missiles at high altitudes, the requirement for satisfactory operation at low air pressures and extremely low temperatures was formulated. When it was later found that it would be necessary to heat the interior compartments of the missiles because of the inability of the flight servo equipment to operate under extremely low temperature conditions, temperature requirements on the television-transmitting equipment could be somewhat relaxed. However, this was not the case with the receiving equipment which would have to operate in an unheated control plane.

The new 300-megacycle equipment, which was to incorporate all the aforementioned features and would avoid the limitations of the 100-megacycle equipment, became known as the SCR-549-T3 and the SCR-550-T3. In addition, a number of improvements were incorporated which had been found to be of importance during field tests with the 100-megacycle equipment. For instance, it was discovered that if the equipment were left in an airplane overnight, and the airplane was parked in an East-West direction, the rising and/or setting sun would permanently injure the mosaic of the iconoscope. The result would be a heavy black streak in the picture where the mosaic had been "burned" by the sunlight. Thus, it became imperative to provide some kind of automatic-shutter mechanism (see Fig. 24) that would protect the iconoscope when the equipment was not in use.

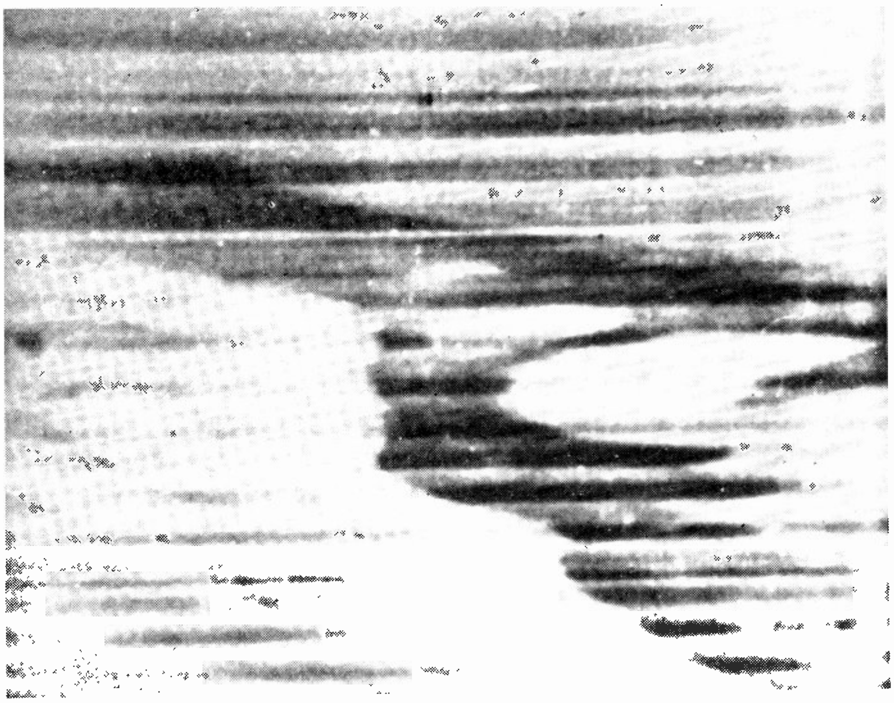

Fig. 23—The same general area as Fig. 22, showing effect of severe low-frequency microphonics (about 700 cycles per second).

Another matter that became important with the field use of this equipment was the problem of fogging of optical surfaces. In the projected use of guided missiles, in which the missile would be carried or flown at high altitudes and then dived into a ground target, the sudden change in temperature, air pressure, and humidity could produce conditions which would make lens fogging so complete that no picture information would reach the mosaic. An investigation showed that it would be necessary to heat the front window of the missile, the front of the television-camera lens, the lens barrel (to prevent the inside surfaces of the lens elements from fogging), the rear of the lens, and the front surface of the iconoscope.

During field tests, it was discovered that interference was caused by vibrations and noises set up in airplanes carrying the television equipment. This would manifest itself as horizontal black lines through the picture. The effect was caused by mechanical and/or acoustical coupling between the equipment and the airplane. These vibrations and noises were causing the elements of the video-amplifier tubes to vibrate with large amplitudes, which, in turn, resulted in a change in transconductance and interelectrode capacitance. In the SCR-549-T1 and T2 equipments, the first stage of the video amplifier was separately shock-mounted, but field tests indicated that this was insufficient. During most of the tests, these microphonics became so bothersome that it was necessary to reduce the low-frequency response of the amplifier, as has been previously described. In the case of the 300-megacycle equipment, an improvement was found by mounting the first three stages of the video amplifier on a separately shock-mounted chassis, as shown in Fig. 25.

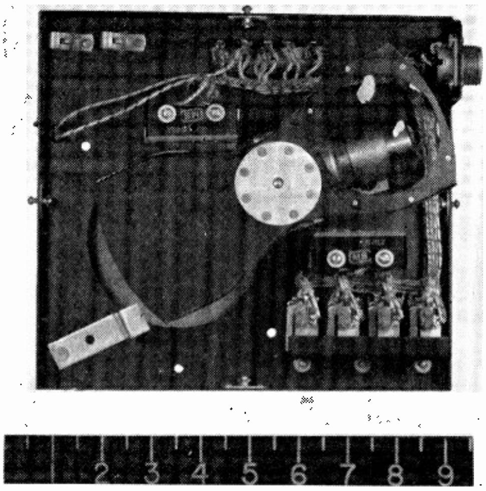

Fig. 24—Interior view of remote-controlled shutter for camera lens. The yellow filter is on the right-hand side in the vane. The driving motor can be seen through the yellow filter.

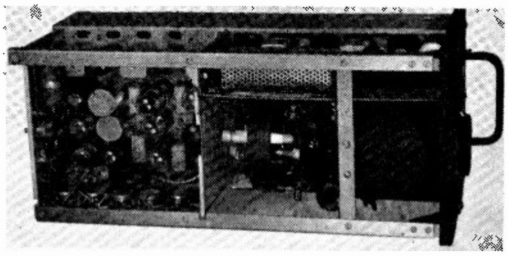

Fig. 25—Top view of camera BC-1211-T3 showing 1846 iconoscope and shock-mounted video amplifier at top right.

During experimental flights with the 100-megacycle equipment at Muroc Lake, California, it was noted that the amplitude of the transmitted synchronizing signals, which were grid modulated, varied with the amount of contrast in the picture. This was a result of the fact that, in this system, no direct-current picture information was transmitted, as indicated before. As a consequence, the synchronizing signals were clipped under conditions of high contrast. Experiments were made with a unit in which the synchronizing signals were plate-modulated instead of grid-modulated. This made synchronization much more stable, and the results were so encouraging that it was decided to make this change permanent in all future equipments.

The operation of the 300-megacycle television set is essentially similar to that of the 100-megacycle equipment, but differs as to details. In the case of the transmitting equipment, Figs. 25, 26, and 27 show that the camera-transmitter unit has been separated into two units. Video and synchronization have been separated and modulate the grid and plate, respectively, of the power amplifier. In the case of the camera (see Fig. 28), the function is the same as in the 100-megacycle equipment. A synchronizing amplifier and mixer have been added to standardize the output to the transmitter and monitor. A novel manner of heating the iconoscope filament eliminated much difficulty with commutator ripple. The filament voltage was derived from a separate 6L6 amplifier tube which was driven by the horizontal sawtooth voltage. As a result, any remaining ripple would be in synchronism with the deflection and would not form moving patterns.

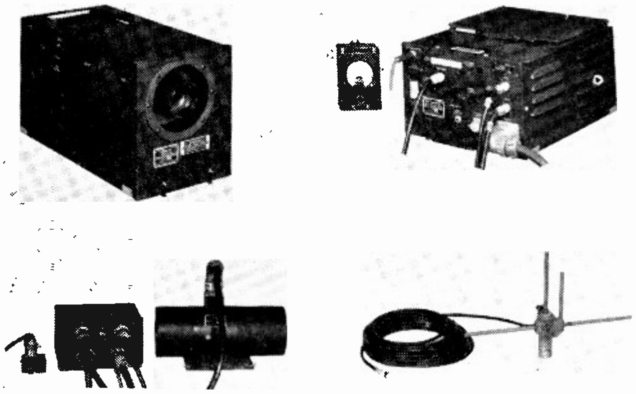

Fig. 26—Radio transmitting equipment SCR-549-T3.

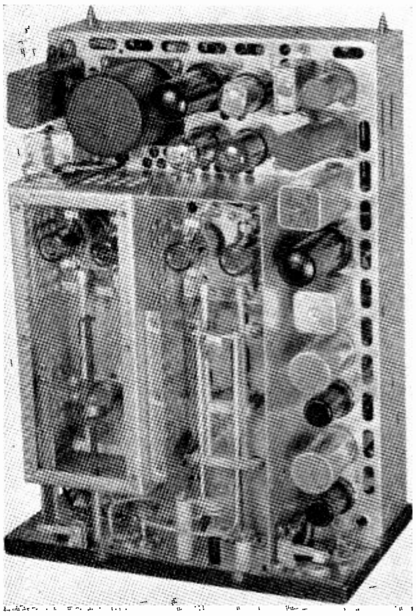

Fig. 27—Radio transmitter BC-1212-T3; master oscillator on left side, power amplifier in center, video amplifier and modulator at left side, and synchronizing amplifier and modulator at top.

Experience with the cameras of early units indicated that more care would be required in the design of the video amplifier with regards to low-frequency microphonics. A leveler or "clamping" circuit was devised such that the low frequencies eliminated by the use of small coupling capacitors in the video amplifier are in effect reinserted by the fifth video stage. Since the amplitude of the leveler pulse from the horizontal output transformer was insufficient, it was fed into the first video amplifier and amplified by the remaining stages. The polarity of this pulse was such that it drew grid current in the fifth video stage.

In the camera section of the 100-megacycle transmitting equipment, a particularly troublesome effect was the formation of a horizontal bright bar across the top edge of the received picture. Because of its intensity, the receiver brightness control could not be advanced to the desired point without having the top edge of the picture "bloom." This bright band of light was very disturbing to the eye and contributed to the difficulty in locating or discerning objects on the screen. The cause was finally determined as an undesired pulse which was produced by the vertical blanking pulse in cutting off the iconoscope beam. This was corrected by introducing a vertical pulse of opposite polarity for the purpose of neutralizing the unwanted effect. The undesired "flare" pulse generally occurred at a time such as to destroy the vertical blanking just prior to the start of the frame. The "flare" blanking pulse restored proper vertical blanking but produced a slightly wider interval than was desired.

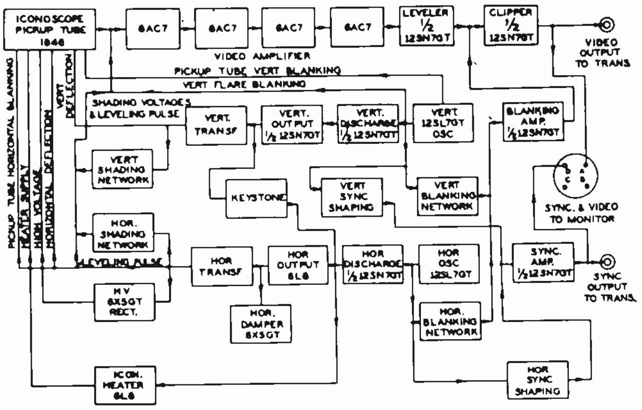

Fig. 28—Functional block diagram of camera for 300-megacycle equipment.

In comparing the functional block diagrams, Figs. 3 and 28, it will be seen that the pickup tube in the T1 camera is a type 1848, whereas that in the T3 equipment is a type 1846. The difference between them, for all practical purposes, is minor; however, from a production standpoint the latter is easier to produce in quantity because of certain simplifications. The tubes can be interchanged in the camera units with only minor readjustments.

Iconoscope bias or back-lighting was incorporated in the T3 and A camera units because of the increase in contrast which resulted.[12] Sufficient light was provided by a Mazda type 313 lamp rated at 28 volts and 0.170 ampere. Early tests did not show a need for bias lighting since they were made under high light conditions. Under these conditions some of the light passed by the lens was reflected, by various means, onto the rear portion of the iconoscope. By this means a form of bias lighting was achieved.

As in the 100-megacycle design, the cathode-follower clipper had a fixed value of grid bias so as to provide a fixed pedestal amplitude. Differing from the first design, the synchronizing signals were not mixed with the video and blanking signals.

From the camera, the video and synchronizing signals were sent to the transmitter over standard 50-ohm coaxial cable, RG-8/U. Their peak amplitudes were required to remain constant in order to prevent excessive variations in the percentage modulation. Video and synchronizing signals were available on another connector of the camera for the monitor unit.

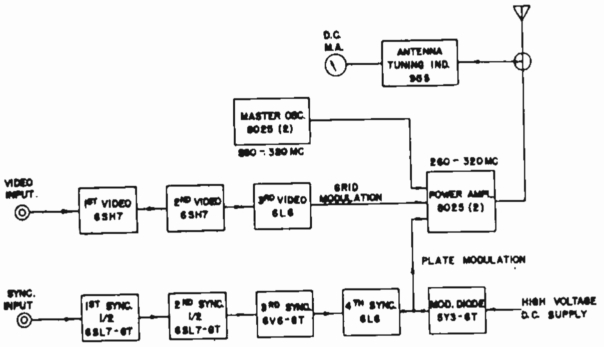

Fig. 29—Functional block diagram of transmitter for 300-megacycle equipment.

The transmitter was designed to cover a range of from 260 to 320 megacycles. This wide frequency range with one set of tuning elements indicated that variable tuned lines would best serve the tuning requirements. The oscillator and amplifier plate lines may be seen in Fig. 27. The filament lines are under the chassis. The type 8025 tube was the only one available, at the time, which met all the requirements.

The video amplifier in the transmitter requires three stages because of gain and polarity considerations. Two high-gain stages would have been sufficient but would not result in the proper video-signal polarity. A modulation control was incorporated in this amplifier in order to compensate for changes in gain produced by vacuum-tube variations.

The synchronizing amplifier requires three stages for gain and polarity considerations, since the fourth stage is a cathode follower. The impedance of the power amplifier is quite low during the time in which the synchronizing signals are to be added to the blanking pedestal. The cathode follower, therefore, provides this impedance-matching function. The plate current for the power amplifier is supplied through the rectifier tube in order that an infinite back impedance be provided to the video coupling tube and power amplifier.

The transmitter was provided with a diode rectifier

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[12] Harley Iams, R. B. Janes, and W. H. Hickok, "The brightness of outdoor scenes and its relation to television transmission," Proc. I.R.E., vol. 25, pp. 1034–1047; August, 1937.

which operated from the radio-frequency energy in the antenna circuit. Tuning of the transmitter was simplified by the use of this indicator. Plate- and grid-current jacks were also provided for ease in tuning of the radio-frequency lines.

The antenna, shown in Fig. 26, consists of a quarter-wave radiator with reflector. A matching stub forms the supporting base and is factory adjusted and fixed to match RG-8/U cable to the transmitter. The ground plane is simulated by a half-wave horizontal rod. Each radio-frequency channel was provided with an antenna designed for that particular frequency.

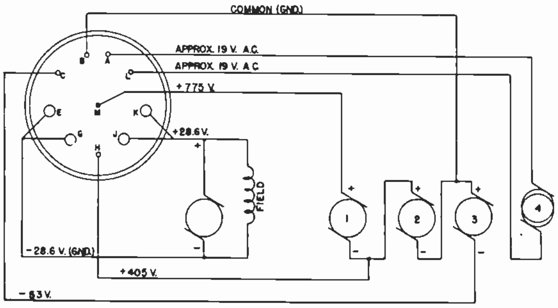

Fig. 30—Diagram of dynamotor showing four output sections on one shaft.

The conflicting power requirements of the camera and transmitter presented a serious problem in power-supply design because of size limitations. A solution was obtained in the dynamotor, as shown in Fig. 30. It will be noted that there are four output sections, two high-voltage, one bias-voltage, and one alternating voltage.

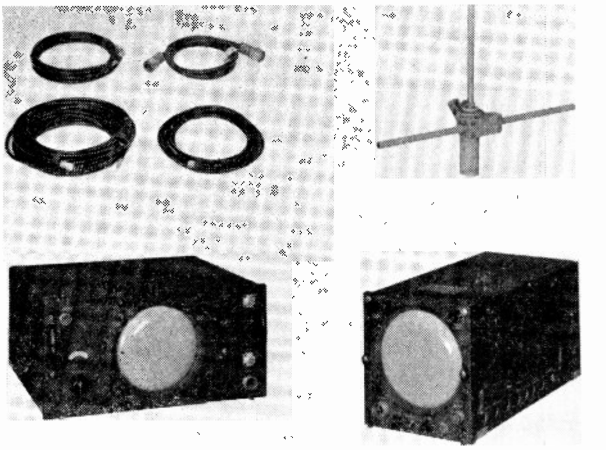

Fig. 31—Radio receiving equipment SCR-550-T3.

The two high-voltage sections are connected in series because of the difference in current requirements at the two voltages. The alternating-current output delivers 19 volts at 90 cycles per second, which is obtained by connecting slip rings to the motor armature coil.

The last versions of the 100-megacycle receivers operated so successfully that it was necessary to make but a few significant electrical changes in order to achieve the 300-megacycle design (see Figs. 31 and 32). The converter section, of course, was a completely new design. In the part of the frequency spectrum around 300 megacycles it becomes necessary to utilize tuned lines as the tuning elements of the radio-frequency circuits. The high loss inherent in the coil and capacitor combinations rule out any thought of their use in receiver circuits, especially those which do not operate at fixed frequencies. This receiver employs two gang-tuned radio-frequency lines for converter and oscillator, respectively. By a suitable choice of gears it was possible to achieve good tracking of the oscillator and mixer lines.

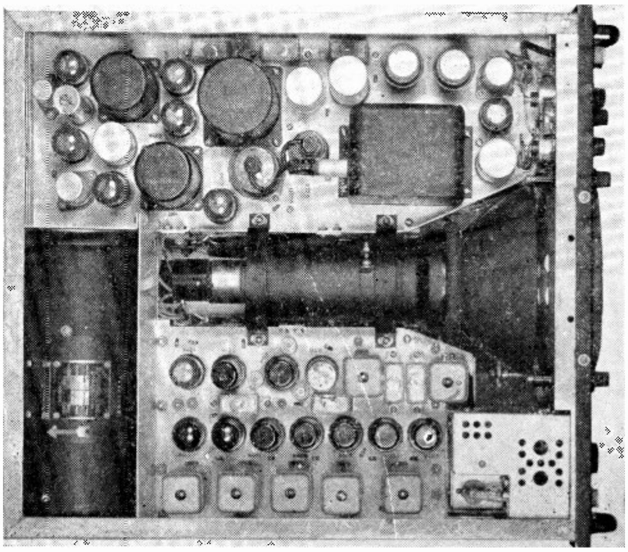

Fig. 32.—Radio receiver BC-1213-T3; top view showing converter, intermediate-frequency amplifier, and video amplifier at the bottom. Deflection and high-voltage circuits are at the top.

The 23.5-megacycle intermediate frequency resulting from heterodyne action is passed through six stages of amplification, and is then rectified to produce a video signal (see Fig. 33). The bandwidth of this amplifier is approximately 9 megacycles. A noise limiter has been incorporated, as in the 100-megacycle receiver. The detector output is amplified and rectified to provide automatic-volume-control voltage to the second, third, and fourth intermediate-frequency amplifiers. The detector is also followed by a three-stage video amplifier whose output voltage is applied to the 7CP1 picture tube.

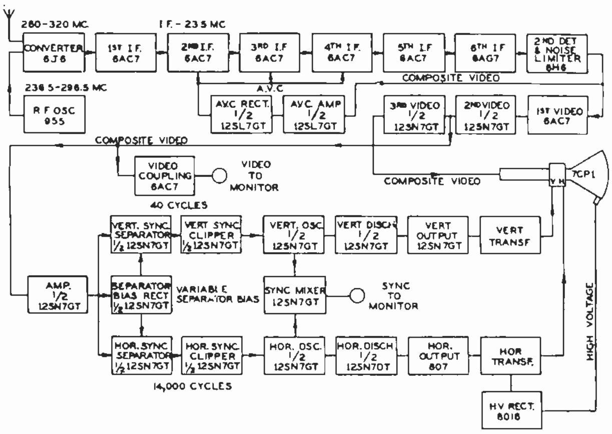

Fig. 33—Functional block diagram of 300-megacycle receiver.

The video signal from the second detector and noise limiter is amplified by another tube and used to drive the synchronizing separators. Here, the video signal is "clipped" and the horizontal and vertical pulses are separated from each other in their particular separators. The clipping-bias voltage is provided to them from the variable clipper-bias rectifier. The resulting pulses, which then have the proper shape, are used to trigger the blocking oscillator and thus achieve synchronization. Each oscillator actuates a discharge tube to produce output voltages of saw-tooth wave form. The discharge-tube output voltages drive the output tubes, which in turn deliver saw-tooth current waves to the secondaries of the output transformer and deflection coils. High voltage for the operation of the picture tube is obtained from the horizontal output transformer and rectified by an 8016 tube.

The monitor unit, as shown in Fig. 34, is of the direct-driven (slave-sweep) type. It can be used either for observing the output of the camera or for providing an additional picture at the receiving location when it is driven from the output of the receiver.

Upon comparison of Fig. 35 with Fig. 33, it can be seen that the monitor duplicates video and synchronizing functions of the receiver. The one exception is that of the resistance-capacitance filter networks for separating the horizontal and vertical pulses. Separation provided here is sufficient to eliminate the need for blocking oscillators and, consequently, any adjustments when operating the monitor. The monitor can be separated from the receiver by any distance up to about 200 feet without loss of picture contrast. The contrast control at the receiver is so designed that it functions as master gain control; that is, a variation in its setting will produce a simultaneous variation in the video grid voltage applied to both the monitor picture tube and the receiver picture tube. This was done in order that the receiver and monitor pictures in a control airplane be identical under all operating conditions. The monitor is supplied with power from a self-contained dynamotor.

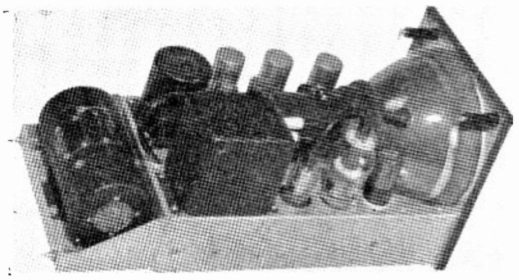

Fig. 34—Monitor unit BC-1214-T3.

The SCR-549-A and SCR-550-A equipments need not be described since they are identical to the T3 equipment except for the quantities produced. A developmental model of the T3 equipment was submitted to the Aircraft Radio Laboratory for approval during December, 1942. Although preliminary inspection showed the equipment as being satisfactory, the first flight test gave an entirely opposite result; that is, the transmitted picture on the monitor was extremely good, but the received picture in another airplane was hopeless. This reversal in the performance was quite a disappointment in view of the previous good performance of the 100-megacycle television equipment.

After a number of flight tests, it was observed that the interference appeared to consist of vertical black bars and dark spots covering the picture and disturbing synchronization. The fact that those phenomena only occurred in air-to-air transmission made it logical to assume that the interference was the result of reflections. After a number of flight tests had been performed it was found that the disturbance was caused by a combination of frequency modulation and multipath transmission of the transmitted signal. It must be remembered that the particular transmitter employed utilized a power amplifier driven directly by a master oscillator, and, unlike the T1 equipment, no buffer stage was used. The master oscillator was tunable from 260 to 320 megacycles and was not crystal controlled. As a result of the modulation process, the power amplifier reacted on the oscillator, which caused a frequency deviation of as much as 200 kilocycles in early models.

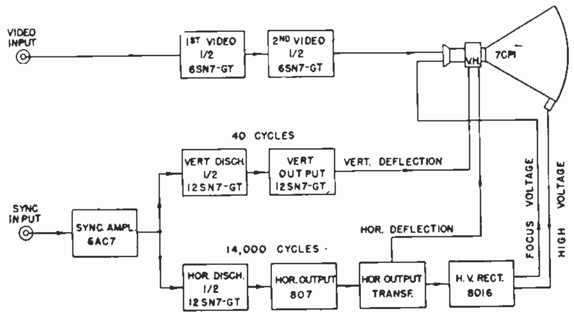

Fig. 35—Functional block diagram of monitor used with camera and receiver.

The combination of multipath transmission and frequency modulation results in the simultaneous reception of two different frequencies in the receiver. This effect has been utilized to advantage in the frequency-modulation radio altimeter, but is undesired in the transmission of television pictures. The resulting beat note, due to the difference in the two frequencies, may be very low and, therefore, within the video band accepted by the receiver. Experiments were conducted to determine the maximum frequency deviation permissible which would not harm the picture. It was believed that any frequency deviation which was less than the picture line frequency, in this case 14 kilocycles, would have no harmful effects on the picture, and subsequent experiments proved this assumption to be correct. As a matter of fact, it was found that frequency deviations of a slightly larger magnitude could be tolerated; that is, up to approximately 20 kilocycles per second. A reduction in frequency modulation was found by changing the tuning procedure of the transmitter, and by reducing the load on the master oscillator. As a result the power output was somewhat reduced, but this did not materially affect the tactical use of the equipment.

Difficulties were also experienced, during early experiments, with the electrical noise caused by the ignition system of the airplane engine. The receiver is very sensitive and ignition interference will manifest itself as small white dots in the picture, closely resembling a snowstorm. In addition, when the speed of the airplane engine is such that the electrical disturbances generated approach the synchronizing frequencies, synchronization is disturbed.

In this particular case, a thorough electrical "clean-up" of the engine ignition system reduced the noise to such a level that it did not affect synchronization. Although some video interference was still present, it was reduced to such a low level that it was not objectionable. Later, when this equipment was installed in tactical aircraft, particular pieces of equipment were often observed to interfere with the television receiver. These cases had to be solved individually, either by the installation of wave traps or by improved shielding.

In general, there are two classes of disturbances that can affect the picture. One class affects synchronization, while the other affects the video information. While any interference that affects the video information may be bothersome, it is not always too serious from a military point of view, as it is often possible to "see through" the disturbances and at least have a picture that is still partly usable. However, if the synchronization is disdisturbed, there is absolutely no information left and the picture is useless.

It might be observed that all through this paper various kinds of disturbances are mentioned which are of varying degrees of importance, according to their effect on the picture. Often one disturbance will affect both the synchronization and the video information, but in general, efforts were always made to eliminate the particular disturbance that affected the synchronization first. In case it would affect both synchronization and video, efforts were made to reduce it to such a point that it would not affect the synchronization, while further improvements to eliminate the video interference could be made later.

DEVELOPMENT OF SPECIAL TEST EQUIPMENT

After the camera-transmitter of the SCR-549-T1 had been in use for a short period of time, the inadequacies of the ordinary laboratory test equipment, especially the 35-millimeter slide projector, for adjustment of the camera-transmitter became apparent. A light projector and test bench, as shown in Fig. 36, were designed at Wright Field to assist in expediting flight tests.

The test bench consisted of an incandescent light source, test slides, projector lens, camera support, dummy antenna, power supply, and controls. By means of this laboratory-designed set, a camera-transmitter could be adjusted for its required final operating performance. Later, a fluorescent-light projector was used as the light source. Transparent slides were used in place of the reflecting test patterns because of the higher light efficiency. As the 300-megacycle equipment took tangible form, operating test equipment became an absolute necessity. The test bench ultimately resolved itself into two units, namely, the I-231 and the I-232 (see Figs. 37 and 38).

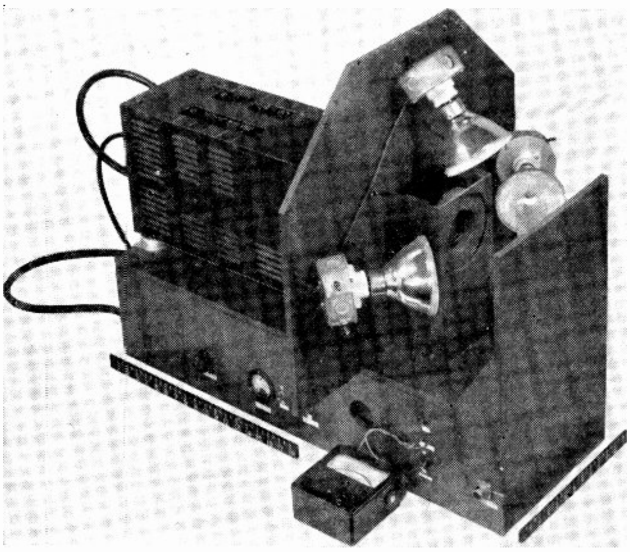

Fig. 36—Experimental test bench with 100-megacycle camera-transmitter in place. The test pattern was placed on the vertical support facing the projector lamps.

The I-231 served several functions, as follows:

(1) A mounting base to align the television camera with the fluorescent projector.

(2) A source of adjustable 28-volt direct-current power having several outlets and a circuit breaker.

(3) 110-volt, 60-cycle outlets for other test equipment.

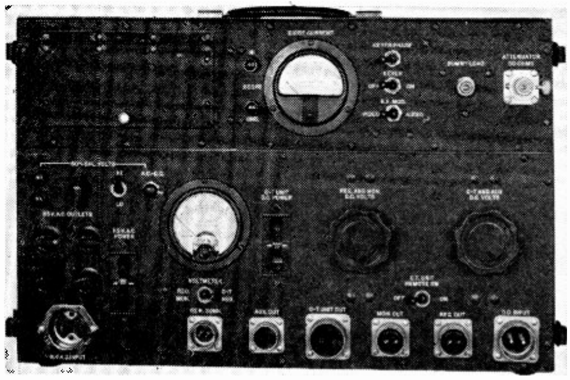

Fig. 37—Test set I-231.

(4) Two ranges of low-voltage, 60-cycle alternating current, for oscilloscope calibration.

(5) Relative-power-output meter.

(6) Percentage-modulation meter.

By means of two cables, one to a source of 28-volt direct current and another to a source of 110 volts, 60 cycles, a complete test setup could be made available on short notice.

The fluorescent projector I-232 had as its light source a 6-watt daylight lamp which matched the spectral characteristics of the iconoscope. There were test slides for contrast, linearity, resolution, and over-all picture quality. A large condensing lens and a cylindrical mirror were used to conserve the light energy, as in Fig. 39. A very convenient feature of this projector was the $8\frac{1}{4}$-inch E.F. lens which projected parallel rays of light onto the television-camera lens. Under this condition, it was possible to adjust the focus of the camera lens to infinity and lock it into position. Thus, it was unnecessary to be concerned about the focus of the camera lens upon the installation of a camera in a missile.

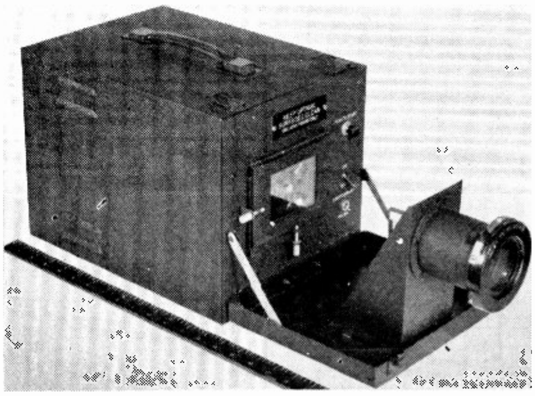

Fig. 38—Fluorescent projector I-232 ready for use.

The fluorescent projector calibration took into account the light loss in the camera lens directly in foot-candles equivalent mosaic illumination. An iris was designed for the front of the projection lens such that it was possible to provide known amounts of light of from one-half to twenty foot-candles on the mosaic. The fluorescent lamp was operated on direct current by means of the self-contained power supply. A current jack was provided so that the lamp current could be adjusted to a fixed and known value. Aging of the lamps within reasonable limits did not produce an appreciable difference in light output, as far as adjustment of a television camera was concerned.

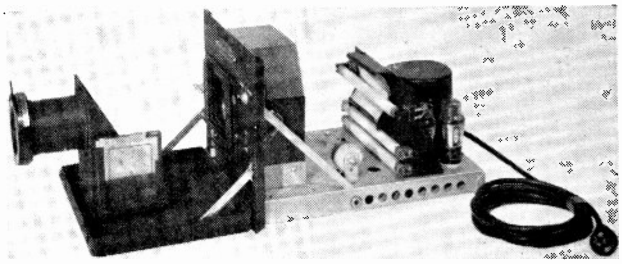

Fig. 39—Fluorescent projector I-232, showing, from right to left, power supply, 6-watt lamp with cylindrical reflector (spare lamps on the bottom), condenser lens with aperture for test slides, and projection lens with iris.

With the advent of tests of the television equipment in aircraft, and particularly in missiles, the need for permanent records of the results became apparent. Missile flights are very short in some cases, and for that reason it is even more important that adequate information be available for critical examination. Engineers differ quite often as to the description of the picture faults, especially if some time has elapsed between the tests and the time of discussion. To circumvent this condition, a motion-picture-camera recorder, shown in Fig. 40, was developed.

The television pictures in this paper were taken by the photorecorder as described above. In the construction of this device it was necessary to mount the television receiver and the motion-picture camera on a common base plate, in order to minimize the effect of differences in the vibration periods of the two units. A driving-motor speed control was used to adjust the speed of the camera shutter to about eight frames per second. Speeds as low as four frames per second were available, if required.

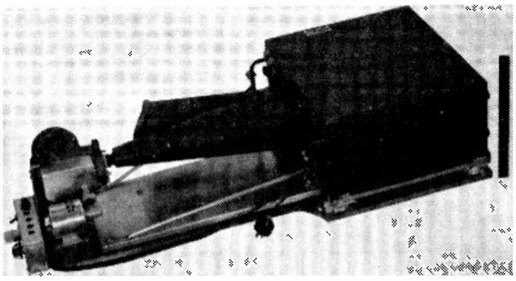

Fig. 40—Motion-picture camera for recording of pictures from the receiver screen. Note the observer's viewing position on left side of light shield.

In viewing the television-screen pictures in this paper, account should be taken of the fact that the picture quality is somewhat inferior to that actually observed on the screen of the cathode-ray tube. There are many reasons for this deterioration, a few of which are listed below:

(1) In spite of the precautions observed in the construction of a photorecorder, certain flight conditions in an airplane will cause the motion-picture camera to vibrate at a different period than the receiver, and a blurred picture will result.

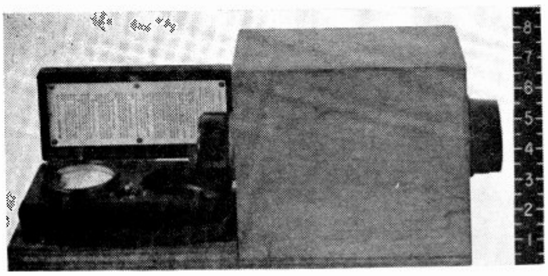

Fig. 41—Weston foot-candle meter mounted in device for obtaining comparative data as to equivalent mosaic illumination obtained at different test locations.

(2) There are many photographic processes between the latent image on the film and the reproduced picture in this paper. Each one contributes very little distortion but the summation of all of them is quite noticeable. There is little that can be done except to use considerable care in all dark-room work.

(3) The picture reproduced on the television-receiver screen is never absolutely steady but has various instabilities that can be attributed to many causes. The

eye will often overlook or correct many of them. At slow shutter speeds of the motion-picture camera, these motions cause noticeable blurring of the picture.

(4) One other factor which reduces the information to be gained from pictures of a television screen is the lack of continuity of action in the still pictures as displayed in this paper. Some of them appear quite meaningless until they are studied for some period of time or an additional description is supplied. In general, if the scene could be interpreted by the naked eye, then a good television picture would reveal almost the same information. This assumes that none of the aforementioned defects are present in the picture; that is, the system is providing its best possible picture.

Illustrated in Fig. 41 is a light-measuring device for determining the equivalent mosaic illumination on the iconoscope. A standard Weston foot-candle meter is used as the indicator. Since the spectral characteristics of the iconoscope and foot-candle meter are dissimilar, a correcting light filter was placed in front of its photocell. A lens similar to that used in the television camera was placed in front of the photosensitive surface. This light meter was used only occasionally, but was quite useful when a new test location was surveyed. Its use was limited to experimental operations.[13]

FIELD TESTS OF 300-MEGACYCLE EQUIPMENT

After the frequency-modulation and ignition-interference problems had been solved, production of the SCR-549-A and SCR-550-A equipments was started and the first models of these equipments were accepted during the month of June, 1943. Preliminary laboratory and flight tests indicated that adequate performance could be expected. At the same time, a small number of GB-4 glide bombs became available, and the first installation of SCR-549-A equipments in GB-4 glide bombs was completed during July, 1943.

The GB-4 glide bomb, shown in Figs. 42, 43, 44, and 45, consists of a standard 2000-pound bomb to which an air frame has been fitted. The flight-servo equipment, radio-control equipment, and television-transmitting equipment are housed in the body of the air frame, while the camera is mounted inside a streamlined nacelle underneath the bomb. Two seven-cell storage batteries connected in series provide the necessary power for the SCR-549-A equipment. The television transmitting antenna is mounted on top of the bomb towards the rear, with the reflector in the forward position.

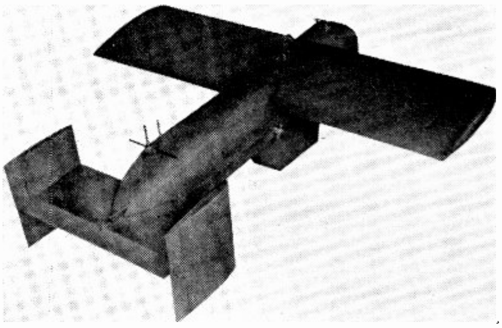

Fig. 43—Top view of GB-4 glide bomb. Television antenna is just ahead of horizontal stabilizer.

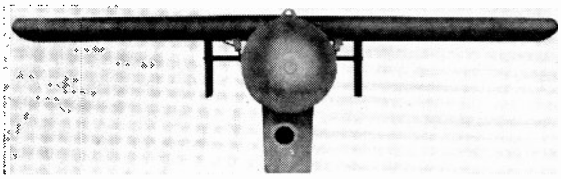

Fig. 44—Front view of GB-4. Note the large frontal area of nacelle due to use of acoustic case around the camera.

After the installation had been completed and all equipment thoroughly checked, flight tests were made with the GB-4 hung under the control plane. A number

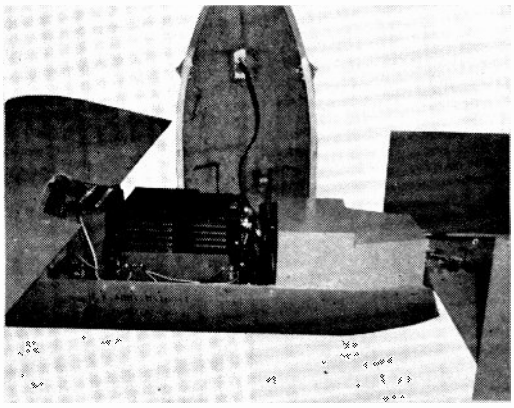

Fig. 42—Glide bomb GB-4 showing transmitter, storage batteries, junction box, and dynamotor in forward section, and radio-control and flight-servo equipment in the rear. Note felt hair on the inside of the air-frame cover.

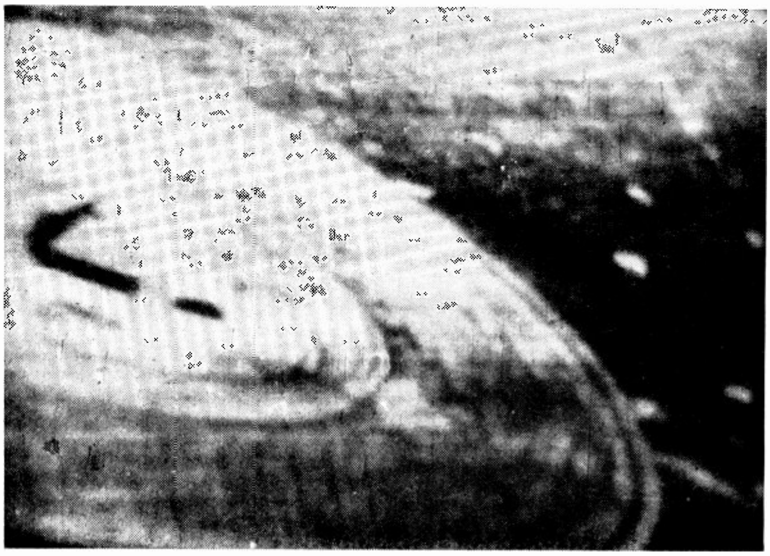

Fig. 46—Television picture received from GB-4 glide bomb turning into pyramidal target at Eglin Field, Florida.

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[13] R. B. Janes and W. H. Hickok, "Recent improvements in the design and characteristics of the iconoscope," PROC. I.R.E., vol 27, pp. 535–540; April, 1939.

of dives were made at the target, consisting of a pyramid (see Fig. 46) to familiarize the control pilot with the television picture. An Air Corps trailer with two dark rooms and completely equipped for field tests served as an auxiliary receiving station during these flights. In addition to having complete test equipment for field alignment and repair of television equipment, the trailer had provision for motion-picture recordings of the television-receiver screen, as described previously.

After the first flight tests indicated that the installation and operation of the equipment was satisfactory, it was decided to drop a number of GB-4 glide bombs to determine the practicability of hitting a small target with this missile. Television equipment was installed in five GB-4 glide bombs which were dropped during August, 1943, at Eglin Field, Florida. Very bad television pictures were received in the control airplane, and in the beginning it appeared as though television in guided missiles could not be successfully realized. The picture was extraordinarily poor, having both horizontal- and vertical-synchronization instabilities, while most of the picture information was obscured by dark lines. In addition, the shading of the camera was generally unsatisfactory. The power output of the transmitter suddenly decreased to zero in one of the bombs after it had been released from the control plane, while on other bombs numerous disturbances would appear during flight. Some of these disturbances, such as the heavy streaking that occasionally would obscure the picture information, were also seen at the ground station. Other disturbances, such as the vertical black bars and those causing loss of synchronization, were observed most frequently in the receiving airplane.

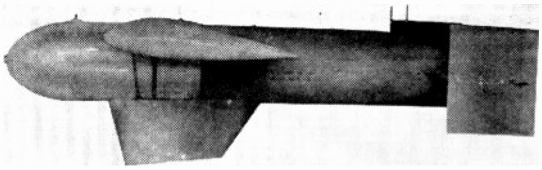

Fig. 45—Side view of GB-4. Slant of bottom of nacelle is due to downward tilt of the camera caused by the flight attitude of the glide bomb.

It was fortunate, however, that motion-picture cameras had been set up to take pictures of the television screen both in the air and on the ground, and thereby a thorough analysis of the disturbances was possible. It was found that most of the disturbances were intermittant and varying in amplitude, enabling an individual analysis from successive frames of the motion-picture film. This investigation showed that the following interference effects were present:

(1) Fine horizontal lines in the picture, as in Fig. 47. These lines were produced by acoustic pickup in the camera, and their frequency was approximately 3000 to 4000 cycles per second. This high-pitched noise was apparently generated by the wind rushing past the GB-4 glide bomb, and a solution was found by placing the camera in a soundproof box.

(2) Heavy horizontal lines in the picture, as in Fig. 48. These lines were produced by acoustic pickup in the transmitter, and their frequency was approximately 120 to 200 cycles per second. This low-frequency noise was apparently generated by the plywood body of the air frame, which acted as an effective sound chamber or resonator. A solution was found by coating the inside of the airframe with automobile-body silencing compound and a thick layer of hair felt (see Fig. 42).

(3) Heavy streaking through the picture, as in Figs. 49, 50, and 51. This trouble was of an intermittent nature, and an investigation showed that the disturbance was caused by loose bonding. For example, one of the metal control rods was approximately one-half wave long with a hinge in the middle. Loose bonding in the hinge was apparently causing these streaks, and after all metal parts had been bonded no further trouble was experienced.

(4) Change in picture shading (see Fig. 52). This change was caused by the influence of the earth's magnetic field on the iconoscope, especially when the video gain control was turned up to a high level. The difficulty was overcome by an improved alignment procedure and installation of a magnetic shield around the entire iconoscope in addition to the shield around the electron gun.

(5) Change in power output of the transmitter. Examination of parts of the television equipment after the crash of several bombs revealed that the antenna tuning capacitor was often completely detuned. Vibrations in the bomb caused the capacitor to change its proper setting and was corrected by installing a clamping spring on the capacitor adjustment screw.

(6) Blooming of the top half of the picture and loss of video information (see Fig. 53). This trouble was caused by iconoscope saturation. Various experiments were conducted with combinations of lens stops and light filters, and it was found that a yellow filter was the most effective solution, especially under conditions of high light levels and low contrast caused by haze.

(7) Loss of synchronization and streaking. This was caused by radio-frequency feedback in the cables going from the camera to the transmitter. Installation of a few by-pass capacitors solved the trouble.

(8) Interference from the radio-control system. The radio-control system then in use utilized five channels between 80 and 90 megacycles. It was found that channel number 5 (88 megacycles) would seriously interfere with channel number 1 on the television band (264 megacycles), this being the third harmonic. The difficulty was overcome by proper selection of radio-frequency channels.

(9) Continuous-wave interference. This would manifest itself in a fine herringbone pattern obscuring the picture in a manner similar to interference produced by diathermy machines. This disturbance was caused by other transmitting equipment in the control airplane. A solution was found by improved bonding of the receiver antenna cable.

Fig. 47—Television picture received from GB-4 glide bomb. Pyramidal target with smoke flare can be seen in background; target information is obscured by heavy microphonics, frequency approximately 3000 cycles per second.

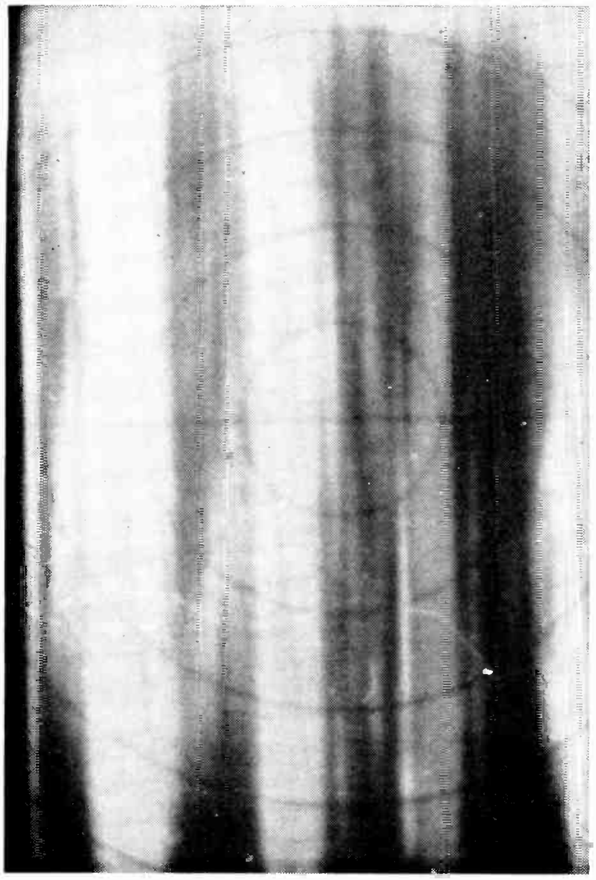

Fig. 48—Television picture from glide bomb shows wide bars due to microphonics of about 200 cycles per second. Target information is completely obscured.

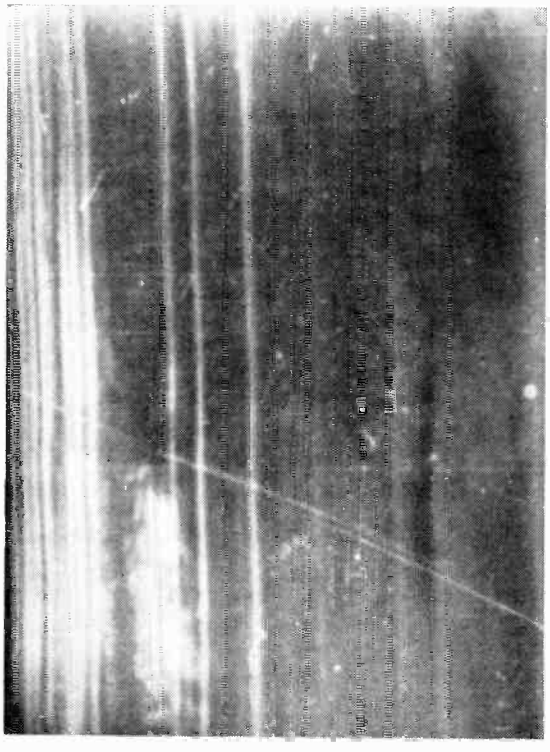

Fig. 49—One of the first television pictures obtained from a glide bomb. White patch in the picture is the target area. White streaks are due to poor electrical bonding. This picture was taken just after the GB-4 was released from B-17 airplane.

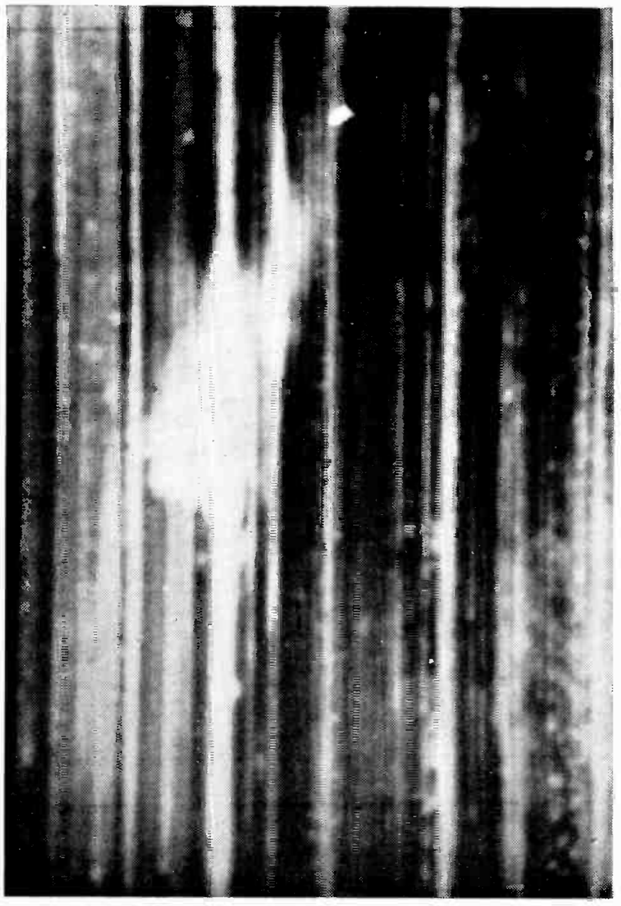

Fig. 50—Pyramidal target practically obscured by white bars due to poor electrical bonding in GB-4 and smaller bars due to microphonics of approximately 3000 cycles per second in camera.

Fig. 51—Pyramidal target with streak due to poor electrical bonding just below it. Because microphonics are less severe, road and trees can be seen in the foreground.

Fig. 52—Mountain range as seen via television from glide bomb. This picture is an enlargement of one frame of a 16-millimeter film. Observe the change in horizontal shading due to the influence of the earth's magnetic field.

Fig. 54—Target area at Eglin Field, Florida. The dark, wavy lines are trees along drainage ditches. The large triangle is approximately 1800 feet on the side.

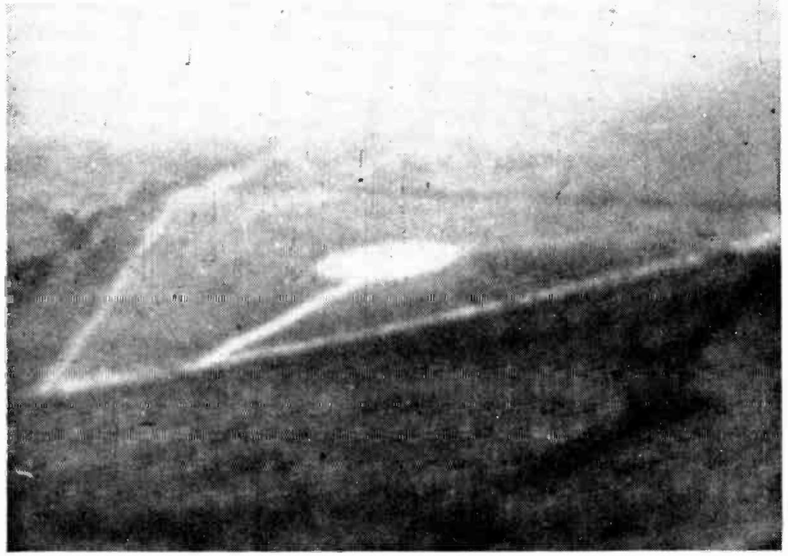

Fig. 55—Target area at Eglin Field, Florida, as seen on the television receiver screen. Pyramidal target is in the center of the circular area.

Numerous other minor difficulties were encountered which occur normally in the testing of a new equipment. These difficulties were solved, however, and by November, 1943, a glide bomb was dropped at Eglin Field in which all these and other improvements had been incorporated. As a result, a flawless television picture was received in the control airplane during the whole flight (see Figs. 46, 54, 55, and 56).

By this time, the tactics of the use of guided missiles became more and more important, and it was realized that in order to make full use of this equipment the range, which was 12 to 20 miles at that time, would have to be increased. Experiments were, therefore, carried out in which a directional, narrow-band receiving antenna was used in the control airplane, instead of the conventional omni-directional wide-band antenna. It was realized that this would necessitate changing antennas on the airplane each time a different television channel was used. However, the increase in range obtained by this procedure (50 to 80 miles) justified the use of this antenna.

In order to permit the control airplane to maneuver freely and still make full use of the directional antenna, a gyro-stabilized antenna mount was designed to keep the directional antenna parallel to the course on which the GB-4 glide bomb had been dropped. This gyro-stabilized antenna mount (see Fig. 57) consisted of an upper part which would rotate, and a lower part which was fixed to the airplane. The upper part contained the gyro mechanism with the pick-offs which controlled the servo motor. The lower part contained the servo motor which would rotate the antenna and upper part. A slip ring on the top of the antenna mount permitted the feed-through of the coaxial antenna cable.

The mount was so constructed that the antenna would be directed forward in its normal position before release of the bomb. After release, the gyro mechanism would become uncaged, keeping the antenna stabilized from then on and still allowing the control airplane to take evasive action.

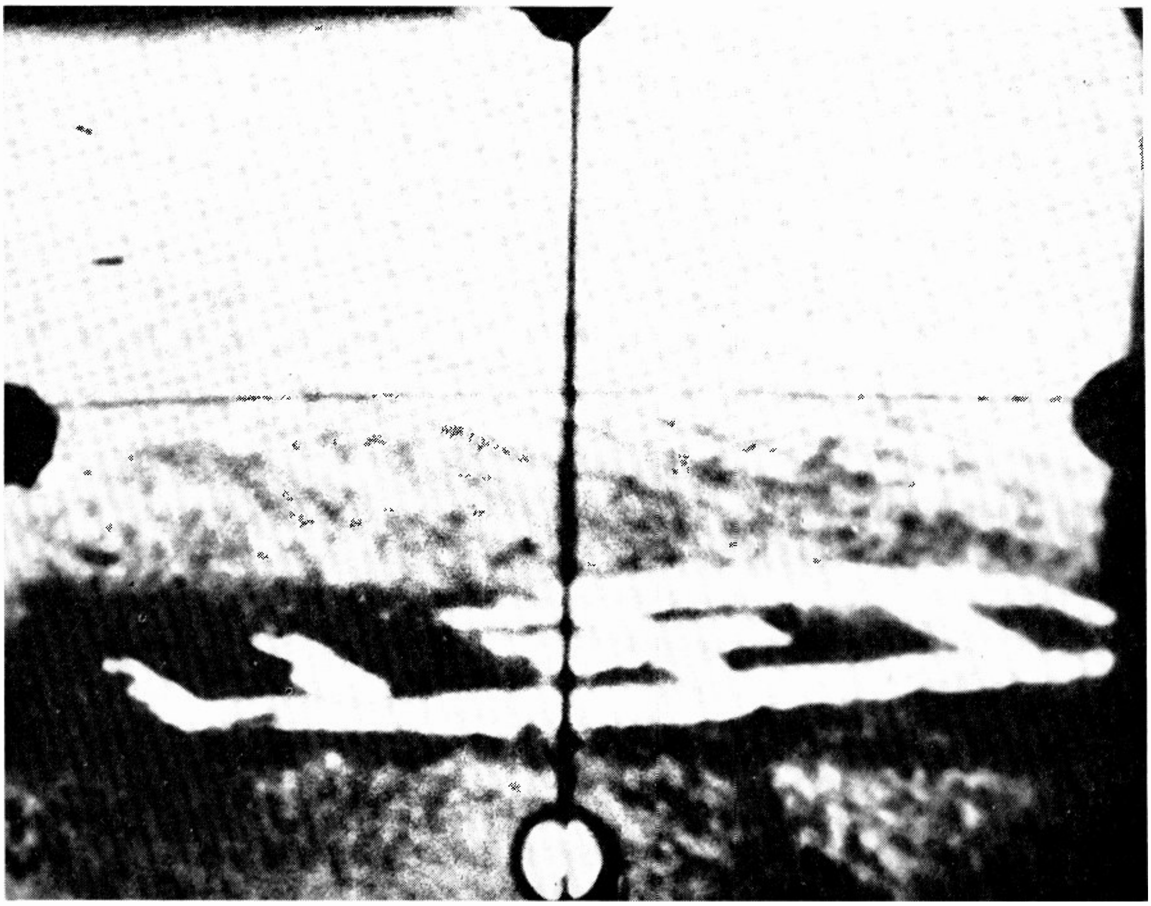

Fig. 53—Television picture from glide bomb, very close to target, Tonopah, Nevada. Parts of the target have been removed. Observe the "blooming" of the top half of the picture due to iconoscope mosaic saturation because of excessive light.

One of the greatest difficulties experienced with the use of antennas in conjunction with this television equipment was the fact that the antenna pattern, obtained by assuming the antenna to be located in free space, is of very little value. The fact that the antenna is mounted on a large metal airplane changes the pattern so completely that predictions are difficult to make. Some work was done by mounting antennas on airplanes in various places that were structurally accessible and that appeared to be likely locations for the antennas. Much was left to guess work and, consequently, many mistrials were made before the final solution was found. At first, it was thought that the camera hatch in a B-17 airplane would be an ideal place to mount the antenna, as the gyro-stabilized mount fitted well in that location. Early experiments proved this assumption to be correct and good pictures were received until an installation was made in a tactical aircraft. The difference was that the tactical airplane had a ball turret (see Fig. 58), while the experimental airplane did not have one. The result was that serious reflections from the propellers and ball turret were encountered in this new airplane. Propeller modulation had not been bothersome before. The antenna was then moved toward the tail, but difficulties were encountered in mounting it in that position because of lack of ground clearance. Empirical data indicated that best results for a B-17 airplane could be obtained with the antenna as far back as possible and at least one-fourth wave below the skin of the ship. A compromise was finally found by mounting the antenna in front of the tail wheel. The installation operated satisfactorily until other considerations made it necessary to change the location again.

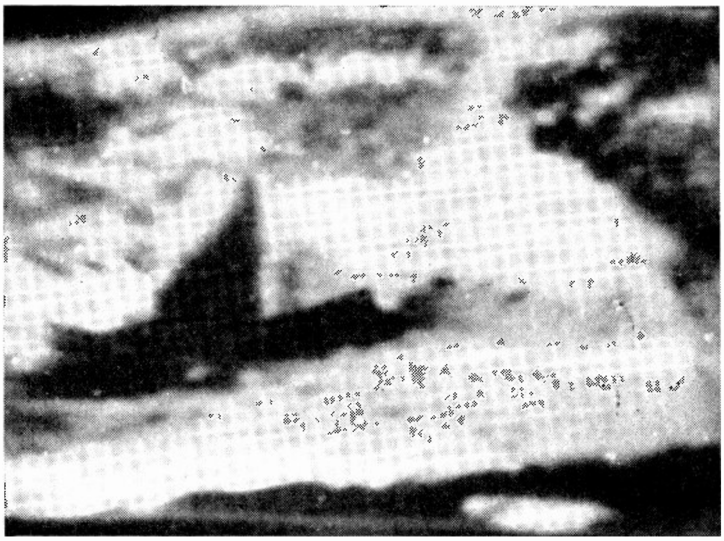

Fig. 56—Pyramid target at Eglin Field, Florida, as seen by television camera an instant before striking it.

After the first television glide bombs had been dropped at Eglin Field and it became apparent that good television pictures could be obtained with this equipment, further experiments were carried out at Tonopah, Nevada (see Figs. 52, 53, 59, and 60). Approximately fifty glide bombs with television equipments were expended at Tonopah and much useful information was gained by these experiments. Specific weaknesses in the equipment were discovered and Army personnel was trained in the alignment and installation of the television equipment.

It was found, for instance, that certain iconoscopes had stronger microphonic tendencies than others, and therefore standards were set up with the aid of an acoustic noise box in which cameras were subjected to certain noise levels, similar to those encountered in actual practice. Iconoscopes could then be used if they passed this noise test.

Troubles were also experienced for the first time with lens fogging, and consequently, optical heating was installed in all sets.

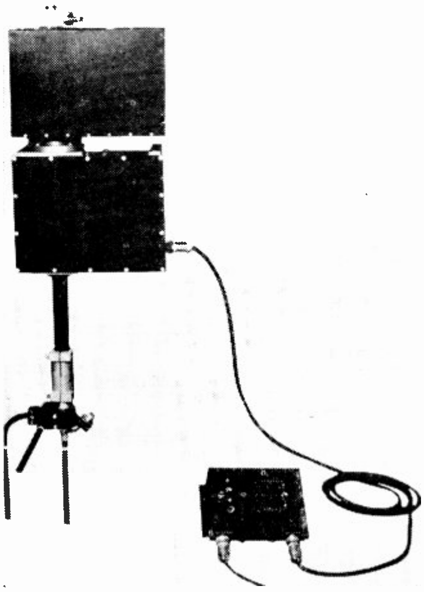

Fig. 57—Gyro-stabilized antenna mount for television receiving antenna on control airplane.

At that time, the first models of the lens shutters were also tested. This shutter (see Fig. 24) consisted of a rotating vane which had a normal opening and a yellow filter. The television operator could select either the full opening or the yellow filter by radio control, according to the light conditions prevailing at the camera.

The problem of reflections showed up when drops were made from altitudes greater than 6000 feet, but they were never too serious and usually disappeared when the bomb reached lower altitudes. A solution was found in changing the flying procedure of the airplane, after the bomb had been released. Although this flying procedure was obtained by sheer luck, it proved to be in accordance with data obtained later, when flights over water showed the reflection problem to be of paramount importance.

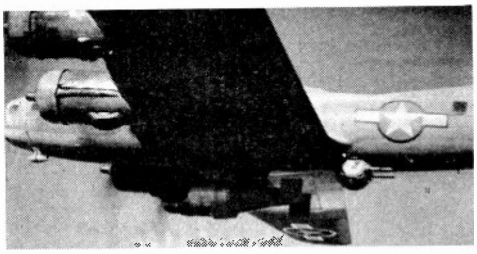

Fig. 58—B-17 airplane with one GB-4 glide bomb suspended on an external bomb rack.

One of the greatest problems in guiding missiles with the aid of television was target identification. In general, targets would be hit, or near misses scored, if the target could be identified, but often the operator, although thoroughly familiar with the terrain, would get "lost." One of the disadvantages of the television set, against a human pilot, is that the television set cannot "look around" in a manner similar to a pilot. Consequently, if for some reason the target is obscured or just outside the picture, it is very difficult to locate. Also, the minimum size of the target which can still be seen is, of course, a function of the viewing angle of the lens in addition to the number of lines used in the picture. The ideal solution would have been to have a lens in which the viewing angle could be changed by remote control, so that if the control pilot got "lost" he could enlarge the viewing angle, which would be equivalent to the "looking around" of a human pilot. The equipment necessary to accomplish this process was found to be too complicated, and more emphasis was put on dropping the bomb accurately with a bomb sight and only using the television set for small corrections in the course. It was then assumed that if no radio control was applied to the bomb it would hit close to the target, but radio control and television were meant to make a direct hit out of what would otherwise be a near miss. Therefore, the viewing angle of the lens was left unchanged, as it was thought to be the best compromise between the size of the area viewed and the ability to distinguish objects.

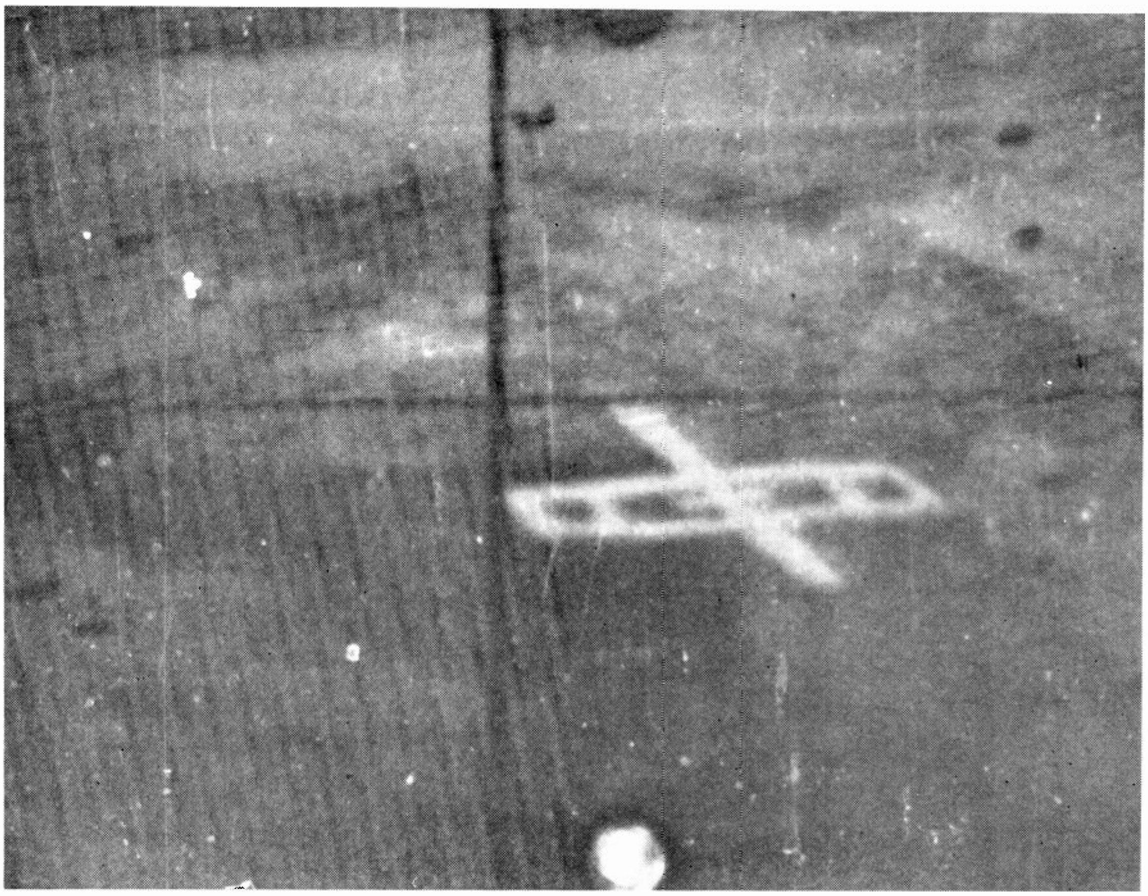
Fig. 59—Target area, Tonopah, Nevada, on television-receiver screen.

A glide-bomb operating group was ordered to England during June, 1944. Shortly afterwards, a "castor" group was sent to the same location.

"Castor" was the code word for the use of "war-weary" heavy bombers as guided missiles. The aircraft were to be loaded with explosives and guided into targets by means of television and radio-control equipment. The television camera was mounted in the nose of the aircraft, while the transmitter, power supply, and antenna were located in the tail. The equipment used was identical to that used in the glide bombs, except that power was derived from the airplane's electrical system and a selsyn compass indicator was added to the camera. This compass projected a course reading directly on a small part of the iconoscope mosaic in the upper right-hand corner. This resulted in the indication appearing in the lower left-hand corner of the received picture. Its image was superimposed on the picture information projected directly from the outside by the lens. An example of such a compass-course projection shows the indicator graduations in the upper left-hand corner of each photograph in Fig. 70.

The receiver installation in the control airplane (see Figs. 61 and 62) was very similar to that of the glide-bomb control airplane. The gyro-stabilized antenna mount, however, had to be operated by manual control instead of by full automatic control.

The first two raids employing GB-4 glide bombs (see

Figs. 63, 64, and 65) were made against the submarine pens at Le Havre and La Pallice, France. These pens were located in such a manner that it was necessary to approach from over water. For tactical reasons it was decided to drop the bombs from 20,000 feet, and a modified flying procedure had to be established to prevent the control plane from getting out of range of the bomb. The new procedure allowed the control plane to fly in the same direction as the bomb for two minutes after release, then turn 180 degrees and head for home. Total flying time of the bomb was about six minutes.

During these first two raids such heavy interference was encountered in the control airplane that the picture was useless for all practical purposes, although occasional glimpses of the target could be seen. An observation airplane, however, which stayed approximately 50 miles behind, had an excellent picture during the whole flight. This ruled out the possibilities of countermeasures and suggested reflections. The particular phenomena that were observed presented themselves in the following forms during one flight of a glide bomb:

(1) During the first minute, a vertical black bar would appear in the picture, approximately one-third picture width from the left side, and approximately one-quarter picture width wide. This black bar would obscure all video information completely and would move slowly to the left, while it was also observed that synchronization was very unstable.

(2) After approximately one minute, the bar would have reached the left-hand edge of the picture, and synchronization became so unstable now that a regular television picture could not be maintained.

(3) After two minutes, the vertical synchronization would at least become stable, while the horizontal still remained unstable.

(4) After three minutes, a violent "flashing" effect was observed in which it appeared as if variations in outside illumination of the scene took place at a rate of about 2 cycles per second. Horizontal synchronization became more stable.

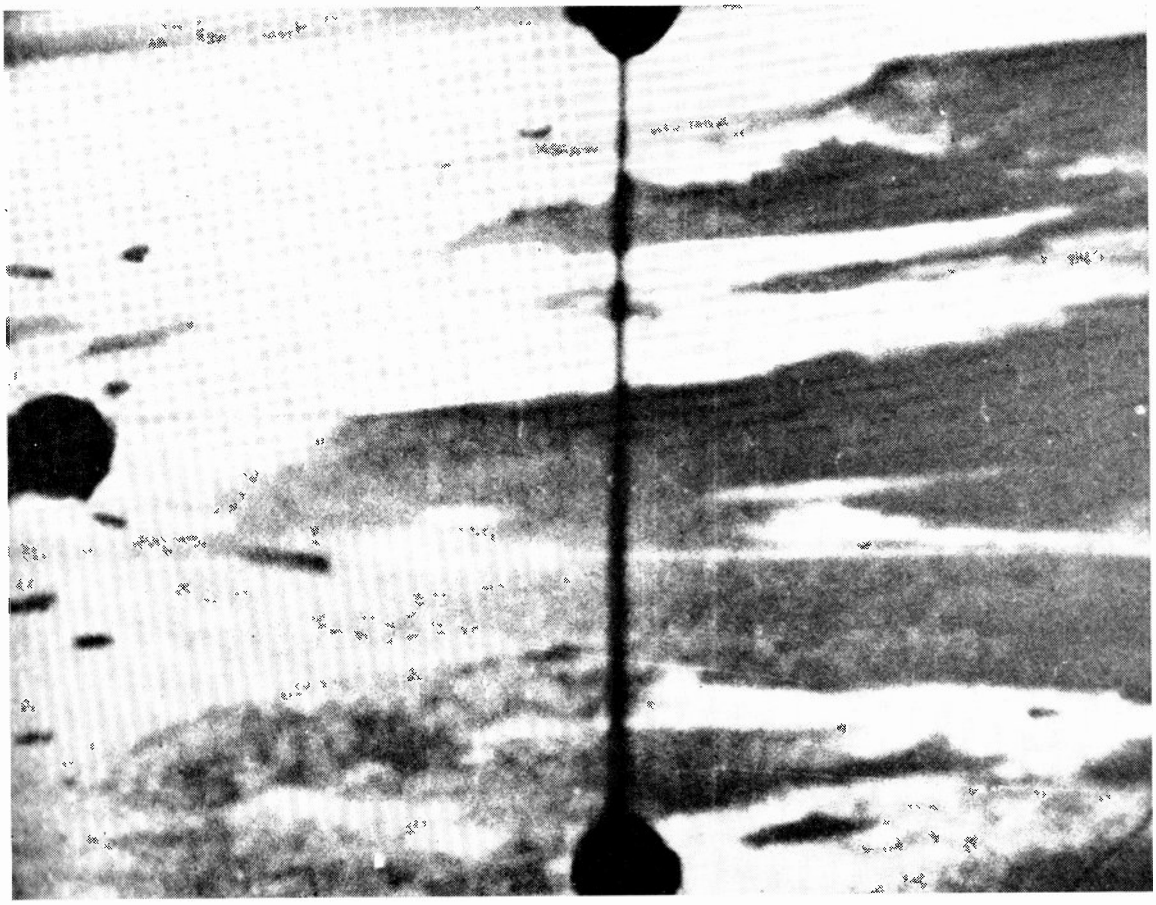

Fig. 60—Television picture from glide bomb close to target at Tonopah, Nevada. Although the contrast is good in this scene, identification of the target is difficult.

(5) After four minutes, synchronization would be stable, the rate of the "flashing" effect would go down to approximately 1 cycle per 5 seconds, but the whole picture would now rapidly oscillate between two fixed positions on the screen; i.e., it appeared as if the horizontal centering control was rapidly turned back and forth at a rate of approximately 5 cycles per second. This rate would slowly diminish until it stopped, and after five minutes, at which time the bomb was at approximately 2000 feet altitude, the picture was stable again.

Many experiments were carried out using other airplanes installed with television transmitters in the role of glide bombs to observe these effects more closely. These airplanes were made to dive at a simulated target at the correct speed, while the control airplane made observations. By analysis of the motion-picture films taken from the screen, it was thought that the vertical black bar was a result of the reflected blanking pulse, while all other effects could be traced to reflections. A typical example of such a test is given to indicate the nature of these reflections. In this test the airplane made a 180-degree turn immediately upon dropping the "bomb" (in this case another B-17 with a complete television-transmitting installation) and the dive was completed in five minutes. The same effects were observed as were described above.

In Fig. 66 it can be shown that the difference in path length between the direct and the reflected wave is

$$X_d = \frac{(h_1 + h_2)}{\sin \alpha}\left[1 - \sqrt{1 - \frac{4h_1h_2 \sin^2}{(h_1 + h_2)^2}}\right]$$

while the angle between the reflected wave and the

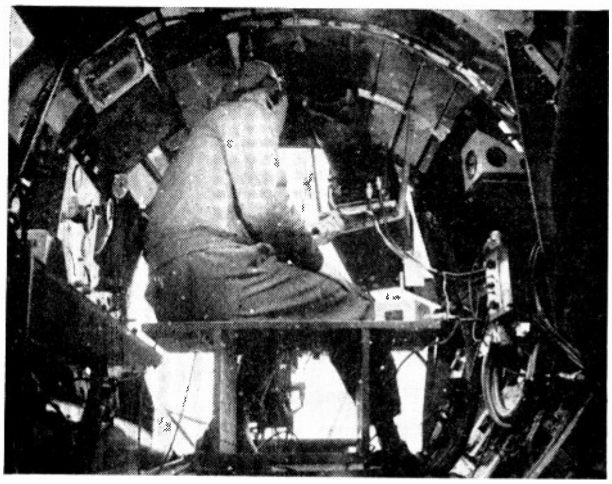

Fig. 61—Control position in nose of B-17 airplane; monitor unit BC-1214-A provides television picture for radio-control pilot.

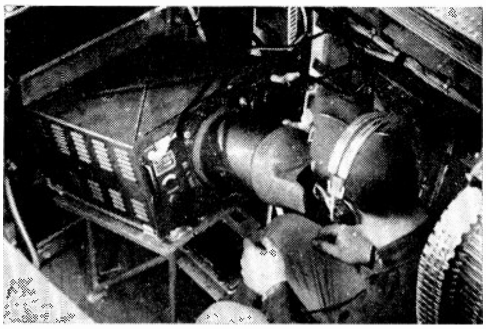

Fig. 62—Receiver installed in radio compartment of B-17 airplane. The television operator monitors synchronizing, contrast, and carrier controls.

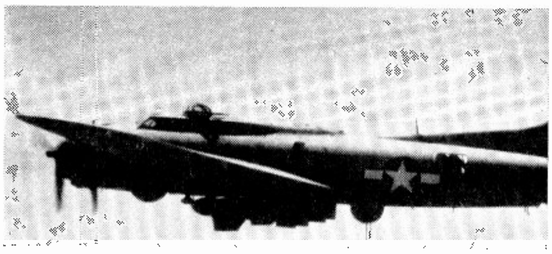

Fig. 63—B-17 airplane carrying two GB-4 glide bombs on tactical mission over Europe.

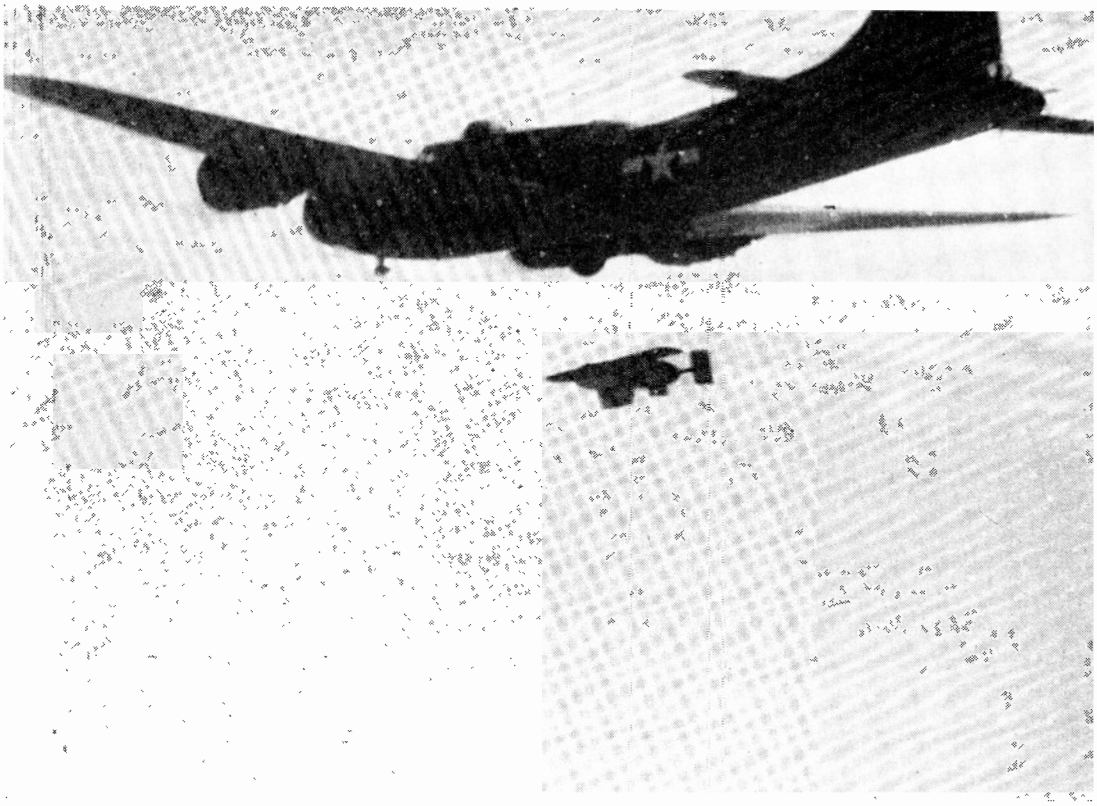

Fig. 64—GB-4 glide bomb just after drop away from B-17 airplane.

ground surface can be expressed as follows:

$$\tan \alpha = \sqrt{\frac{(h_1 + h_2)^2}{d^2 - (h_1 - h_2)^2}}.$$

Substituting the flight data for this particular flight, a graphical representation is shown in Figs. 67 and 68. It was observed that the picture was reasonably useful after three minutes on this particular flight, which corresponds to an X_d of approximately 3000 feet and an angle α of approximately 15 degrees.

An analysis of the problem shows that reflections can become a serious detriment when the following conditions prevail:

(1) The ratio of direct signal strength to reflected signal strength is low.

(2) The distance X_d is larger than approximately 3000 feet, or roughly 20 per cent of the blanking pedestal.

(3) The reflection angle α is larger than approximately 15 degrees.

This explains why these reflection phenomena were never observed when glide bombs were dropped from altitudes of 6000 feet or less. Just after bomb release, the ratio of direct signal strength to reflected signal strength will be high. When glide bombs are dropped over water, the signal strength of the reflected signal at the receiver will be high, effectively keeping the ratio of direct to reflected signal strength low. In the case of the drops from 6000 feet, as soon as this ratio had diminished to a point where reflections could be expected, the value of X_d and α was so low that the reflected wave was further attenuated to a point where it was ineffective.

Inasmuch as it is impossible to control conditions (2) and (3) in the dropping of glide bombs, a solution to the problem was found by keeping the ratio of direct to reflected signal strength as high as possible. This was done by mounting the television receiving antenna on top of the horizontal stabilizer of the control airplane in such a manner that the line between the top of the receiving antenna and the trailing edge of the stabilizer resulted in an angle of 12 degrees with the horizontal in normal flight. This angle corresponded to the angle (see Fig. 66) between the line "receiver-transmitter" and the horizontal, after three minutes of flight. This solution was so successful that no further difficulties were encountered with this reflection problem.

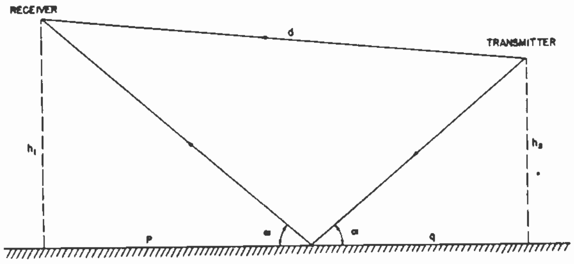

Fig. 66—Geometrical relationship between direct and reflected wave.

A series of frames from a motion-picture film, taken

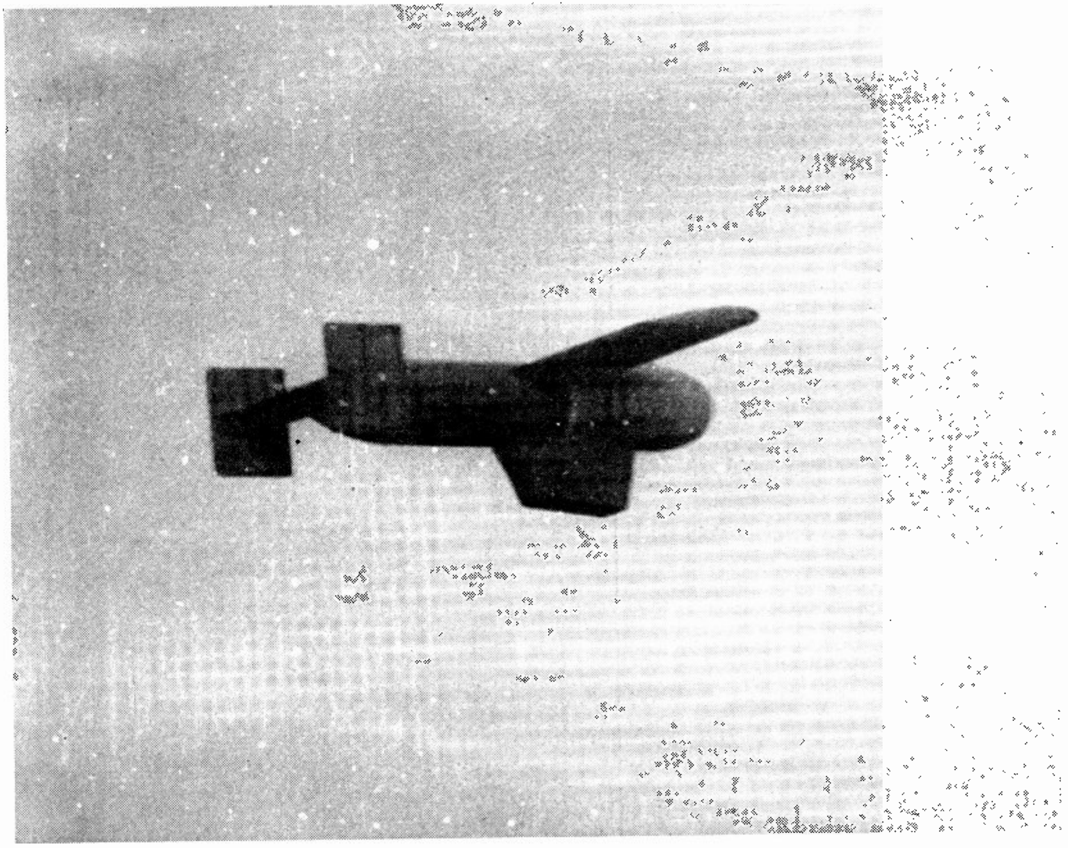

Fig. 65—GB-4 glide bomb on its way to the target. Note that the television camera is tilted downward because of the flight attitude of the bomb.

from the television screen on one raid, is shown in Fig. 69. The particular iconoscope used in this camera had a number of small spots on the mosaic which can be seen all through the picture. The target was located in a small village, identified by the dark woods which can be seen clearly in the background of the second picture of Fig. 69. A large white church and several houses are clearly visible as the bomb nears the target. Banking of the picture indicates that corrections to the flight path of the bomb are being given by radio control.

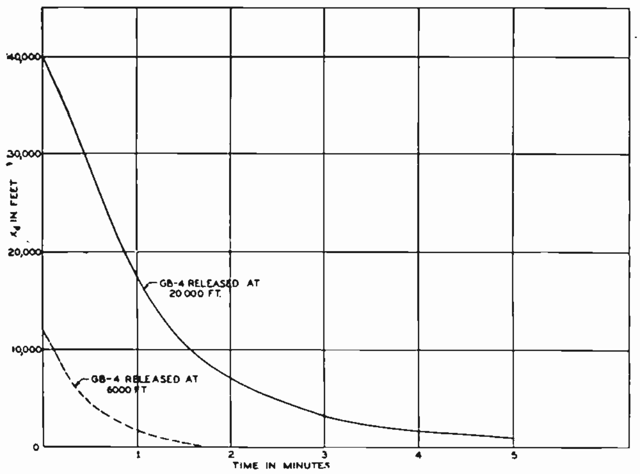

Fig. 67—Relationship between path difference and time after drop of GB-4 from B-17 aircraft at normal speeds. Release altitudes of 20,000 feet and 6000 feet.

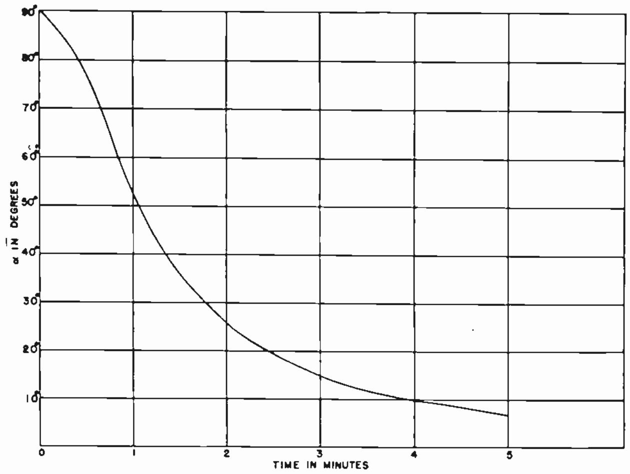

Fig. 68—Angle of reflected signal versus time for B-17 and GB-4 aircraft under the same conditions as described in Fig. 67.

The question of target identification played an important role in selecting targets for guided missiles employing television equipment. The submarine pens at Le Havre (see Fig. 71) and the installations on Helgoland (see Fig. 70) constitute an ideal target for guided missiles of this nature. The pens in Fig. 71 are located at the corner of an excellent landmark, the rectangular harbor basin, which can be seen from a great distance. In general, it was observed that the television picture is approximately 50 per cent as effective as the direct picture seen by the human eye. In addition, the small angle under which the target is viewed makes haze interference a serious problem. Therefore, it is imperative that targets can be easily identified in the picture by being located near prominent landmarks, such as the one illustrated in Fig. 71.

The development work described in this paper was performed during the period from 1941 to 1944, inclusive.

CONCLUSIONS

In conclusion, it may be said that airplane-to-airplane transmissions of television pictures are feasible. Many difficulties still may be encountered, but in general, successful transmission may be accomplished if the following precautions are observed:

(1) Transmitting equipment must be protected from interference produced by acoustical noises encountered in aircraft. Receiving equipment must be protected from interference produced by electrical noises encountered in aircraft.

(2) A stable master oscillator must be used in the transmitter, preferably followed by a buffer stage, in order to keep the frequency deviation due to frequency modulation less than the picture-line frequency.

(3) The ratio of direct-to-reflected signal strength in the receiving airplane must be kept as high as possible.

Compact lightweight television equipment can be used in guided missiles, and clear pictures, free from all interference, can be obtained if the aforementioned points are heeded.

(4) The contrast of the viewed scene must be high and possible targets should be located close to prominent landmarks so that they can be located easily.

ACKNOWLEDGMENT

The material in this article represents the efforts of many engineers, in addition to those of the authors. In particular, much credit is due the engineers of the RCA-Victor Division of the Radio Corporation of America for the original design and to the engineers of RCA and the Farnsworth Television and Radio Corporation for the solution of the many production problems. In addition, invaluable help was received from other members of the television development group, Radio Control Branch, Aircraft Radio Laboratory, and from the members of the Special Weapons Branch, Equipment Laboratory, Wright Field, who assisted in the field testing of this equipment. Many contributions to the art of using television equipment in guided missiles were made by the engineers of the Bureaus of Ships and of Aeronautics, Navy Department.

No small amount of assistance was provided by the National Defense Research Committee in the sponsorship of research endeavor which has resulted directly in the success of this development.

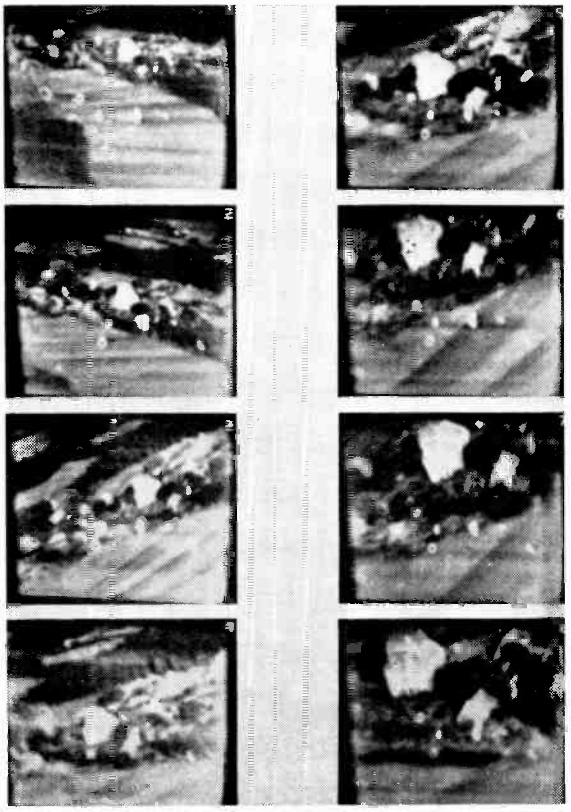

Fig. 69—A series of stills taken from motion-picture film showing glide bomb approaching target in Germany.

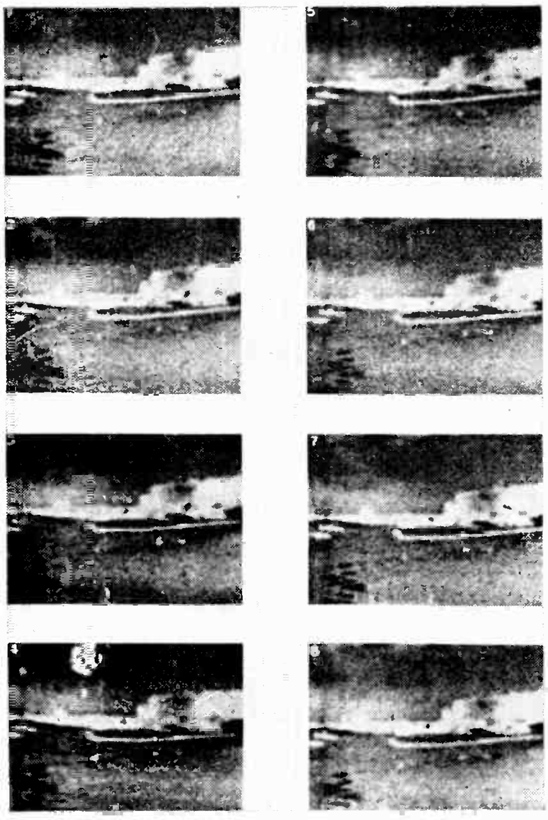

Fig. 70—A series of stills taken from motion-picture film showing the television screen of a "war-weary" missile approaching target at Helgoland, Germany. The island and harbor area can be seen. Observe compass course projection in lower-left-hand side of the picture. Also note antiaircraft fire in Frame 4.

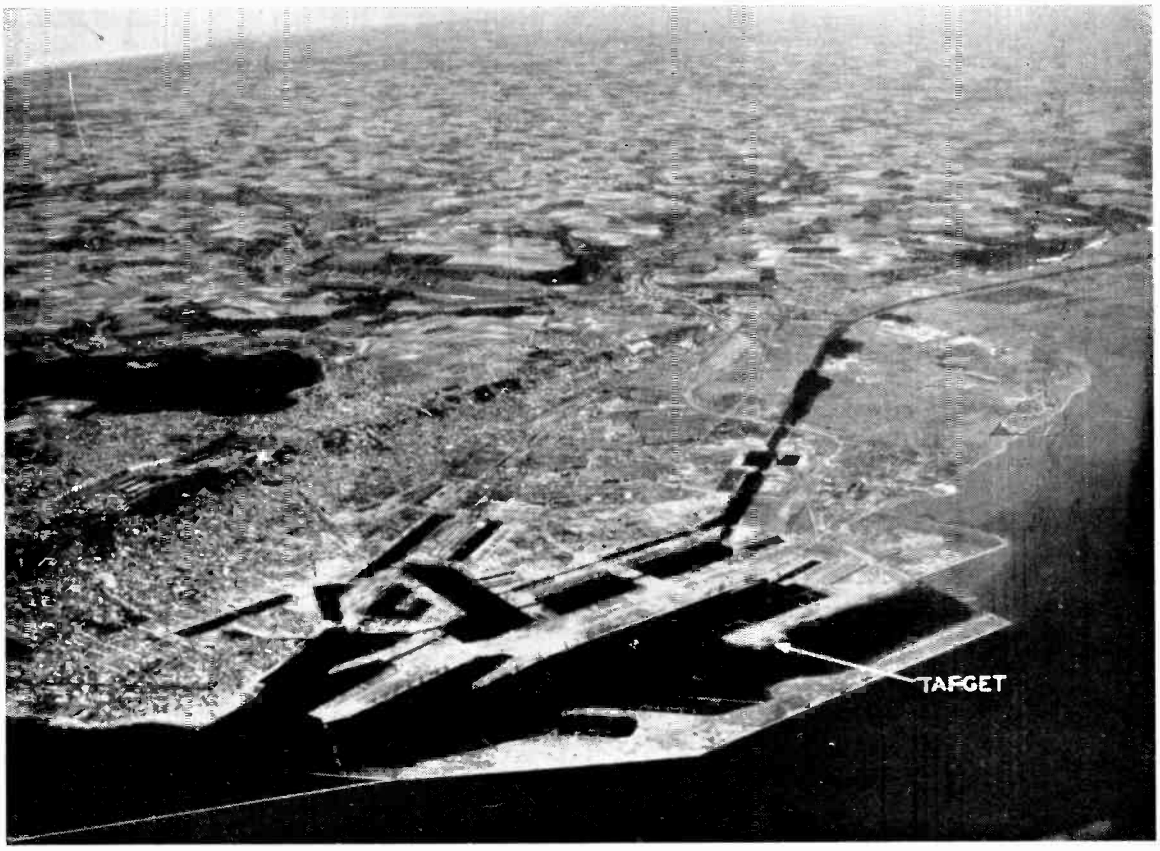

Fig. 71—Reconnaissance photograph of a good target area for guided missiles. Because of the lower resolution, the television equipment would show only the major outlines or patterns.

The Cathode-Coupled Amplifier*

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Summary—**This paper gives the reader a picture of the operation of the cathode-coupled amplifier and a study of methods of application in several new directions. Among these are the following: high-frequency amplifiers, multivibrators, audio oscillators, radio-frequency oscillators, resonant-resistance determination, mixers, and other applications.**

This list is by no means all-inclusive, but does show some of the capabilities of this unique circuit.

I. INTRODUCTION

THE AUTHORS of the paper "Cathode-Coupled Wide-Band Amplifiers"[1] have made an excellent beginning in opening this interesting subject to the industry. They have pointed out a number of the properties of the unit and have indicated the extremely wide field in which this circuit will be found useful. The writer, for a number of months, has been experimenting with the same basic circuit, and has found a number of other forms in which the circuit is very valuable. Most of these properties have their basis in the extremely wide-band characteristics which result from the use of the high-impedance input existing in the cathode-follower tube and the combination of the shielding feature and impedance stabilization resulting from the use of the grounded-grid amplifier.

II. THE HIGH-FREQUENCY AMPLIFIER

The advantages of the cathode-coupled amplifier for high-frequency work result from the fact that the tuned circuit can be used at its full impedance instead of having to tap the coil for the input lead, as is necessary for use in ordinary circuits. If the grounded-grid amplifier alone is used, the coil or tuned circuit has to be tapped at a sufficiently low impedance that the input impedance is approximately the reciprocal of the mutual conductance. Otherwise, gain is lost by degeneration and by the fact that there is a limit to the plate-circuit impedance at these frequencies. If, for example, the plate-circuit capacitance is 2 micromicrofarads, and the plate-circuit Q is 50 micromicrofarads, with the frequency 100 megacycles, then the maximum impedance in the plate circuit will be the product of circuit Q multiplied by the capacitive reactance; namely, 800 times 50, or 40,000 ohms. As a grounded-grid amplifier, the effective amplication is reduced by the square root of the impedance transformation in the cathode or plate. For this stage to operate properly, it is necessary for the input impedance Z_i to be less than the cathode impedance Z_k and also small compared to $(R_p+Z_L)/(1+\mu)$. (These formulas are verified in the Appendix.) The input impedance is thus required to be small. In the case of a 6J4 tube, for example, it would have to be less than 100 ohms. This requires tapping down the cathode input. The result is a voltage loss proportionate to the square root of the impedance ratio. If the tap were at 100 ohms, for instance, there would be a voltage step-down of 20 to 1. However, should the cathode-follower input circuit be used, the impedance step-down would be accomplished with a voltage loss of approximately 2 to 3. This gives an effective voltage gain of the cathode-follower stage of from 6 to 10. It must be noted that the series equivalent impedance of the cathode-follower stage is given approximately by the formula $Z=(Z_k+R_p)/\mu$. Hence, it is necessary that the cathode impedance in the circuit be small, or loss in the cathode-coupled stage would be experienced. This is the reason for choosing the cathode impedance approximately equal to the reciprocal of the mutual conductance. This also accounts for the impedance relation from cathode to plate in Section VIII, which follows. If the gain of the grounded-grid section were 20, therefore, the combination effective gain would be approximately 200, compared to 20 for the grounded-grid amplifier. The advantage of the cathode-coupled amplifier is shown in this application. The circuit appears in Fig. 1.

III. THE MULTIVIBRATOR

This circuit also makes a unique type of multivibrator. It is the only simple multivibrator having identical wave form on the two half cycles. This results from the fact that at no time is the cathode current cut off as a result of the cathode follower, nor is either grid conducting at any time. It is believed to be the most simple multivibrator with the widest range so far developed. With no difficulties, the circuit has been used, running free, at as high as 3 and 4 megacycles. A simple clipping operation will turn the stage into a square-wave generator. If so desired, the proportions of the two halves of the wave may be changed easily by placing the two grids at different direct potentials to ground. By biasing one grid to cutoff, a countermultivibrator can be made. Placing a differentiator circuit to pulse the blocked multivibrator causes the unit to trip over once for each positive or negative pulse. A direct-current microammeter will integrate the pulses and give a direct reading of pulse rate. This arrangement, in fact, can be made to do everything that the standard multivibrator will do, and a good many things not easily achieved by it. Uniquely enough, as can be noted in Fig. 2, in addition to a single capacitor and a single resistor in the frequency-determination circuit, only two resistors are required to make the unit.

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† The Pullen Laboratories, Brooklyn, N. Y.

[1] G. C. Sziklai and A. C. Schroeder, "Cathode-coupled wide-band amplifiers," PROC. I.R.E., vol. 33, pp. 701–709; October, 1945.

IV. THE AUDIO OSCILLATOR

A resistance-tuned audio oscillator can be built very simply by minor modifications of the multivibrator. The single resistor and capacitor are replaced by two resistors and two capacitors so arranged that one set is in series and the other in parallel. The feedback regulation, as can be seen in Fig. 3, is accomplished by placing a lamp bulb in the cathode circuit of the tube. Here, again, the extreme simplicity of the circuit is self-evident. The extra coupling circuit is eliminated, as are the parts usually supplying the screen. As in the case of the multivibrator, this oscillator operates with ease far beyond the normal range of the ordinary resistance-tuned oscillator. These units have been operated satisfactorily at frequencies as high as 3 megacycles with excellent stability. With no voltage regulation, the frequency drift was found to be less than 1000 cycles at 1 megacycle. For extending the range into still higher frequencies, an additional cathode follower may be placed between the grounded-grid amplifier plate and the frequency-determining circuit. Interaction of that circuit on the system is then eliminated. However, stray capacitances should be watched in this case.

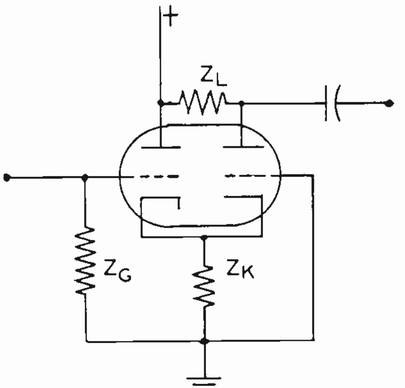


Fig. 1—Basic circuit of cathode-coupled amplifier.

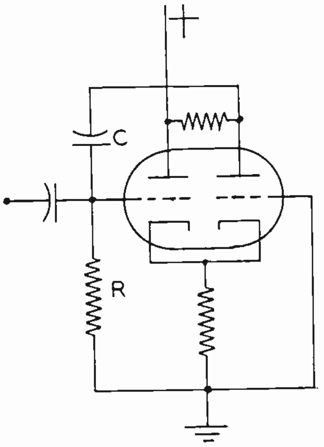


Fig. 2—The multivibrator circuit.

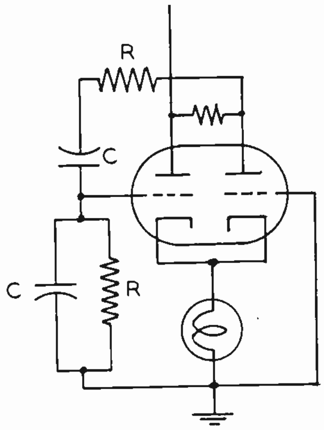


Fig. 3—The resistance-capacitance oscillator circuit.

V. RADIO-FREQUENCY OSCILLATORS

There are several methods of making the circuit into an oscillator in addition to the one noted in the literature.[1] There are methods of using series-resonant circuits and methods of using parallel-resonant circuits. The simplest circuit, Fig. 4, and the one in general use in our laboratory, uses a type 6SN7 tube, with the common cathodes connected to ground through a 300-ohm resistor. The grounded-grid tube has a plate resistance of 10,000 ohms. A small capacitance, from 5 to 50 micromicrofarads, is placed from this plate to the cathode-follower grid. The tuned circuit is placed from grid to ground. The resulting oscillator has very high stability. At 1400 kilocycles it is within 500 cycles of final frequency within 25 seconds after being turned on. The frequency variation from line variations of ten per cent is of the order of 100 cycles. Modulation of the unit is accomplished simply by introducing the alternating voltage on the normally grounded grid. The percentage of modulation possible without serious distortion is 50 per cent. A cathode follower supplying 10 volts is ample for this modulation. Little if any frequency modulation results, none being detectable on ordinary receiving equipment. However, no frequency-modulation equipment was available for confirmation of this fact. The crystal filter indicates the series of fixed peaks which would occur in the absence of frequency modulation. Operation of the oscillator in this form has been observed to frequencies as high as 158 megacycles. Even at this frequency, the oscillator did not drift more than ±10 kilocycles at 40 megacycles. This implies a limit of about 40 kilocycles at 158 megacycles. Yet no voltage regulator was used, and there was no swamping capacitance to eliminate thermal effects.

The series-resonant circuit makes use of this element connected from grid to ground on the grounded-grid tube (Fig. 5). If the amplifier is so designed as to amplify the frequency of the resonant circuit, and the feedback circuit will pass the frequency, then oscillation takes place very readily. Little data are available on the characteristics of this circuit, as the other oscillator is of much more immediate use.

These circuits can be used for testing both series- and parallel-resonant circuits for oscillation, and also can be used in conjunction with a tuned circuit and calibrated variable capacitor for the measurement of dynamic circuit stray capacitance.

VI. RESONANT-RESISTANCE MEASUREMENTS

It is simple to set up a unit for measurement of quality of coils, capacitors, and tuned circuits with the oscillator design mentioned in the previous section. Application of a resistor in series with the feedback line to the tuned circuit stabilizes the combination so that results are reproducible. In this case, the cathodes are coupled by way of a variable resistance connected between them. The circuit is shown in Fig. 6. A grid-leak system is placed in series with the grounded grid for introduction of a grid-current microammeter. Use of this as an oscillation indicator completes the unit. As noted, either coils, capacitors, or complete tuned circuits can be tested with this unit. The cathode control is calibrated directly in shunt resistance. It is desirable to use a pentode cathode-follower tube in order to minimize the input capacitance. The screen is by-passed to the cathode, eliminating the grid-to-screen capacitance.

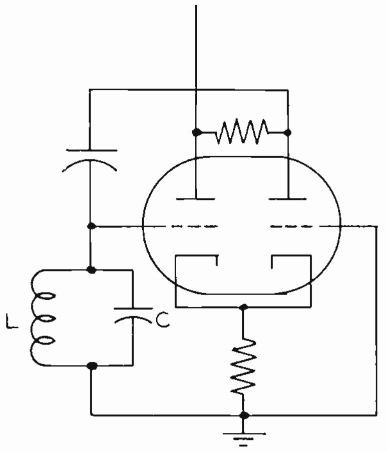


Fig. 4—The shunt-circuit oscillator.

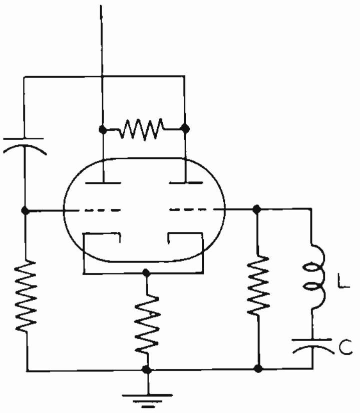


Fig. 5—The series-circuit oscillator.

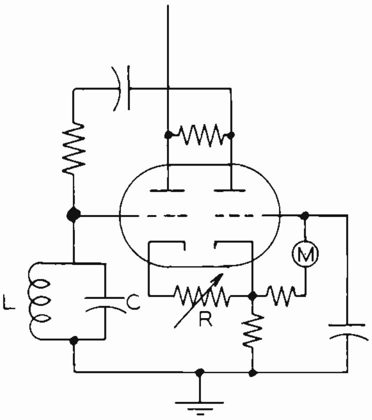


Fig. 6—The resonant-resistance meter.

VII. Mixers

There are several methods of using this circuit as a mixer. The simplest method known to this writer is the injection of both the signal and the local oscillator into the input resonant circuit by way of a link coupling. (Fig. 7.) The grid circuit is coupled to the grid through a grid leak. This grid leak is of such a value as to permit passage of low frequencies up to the intermediate frequency. Then the cathode and plate circuits contain circuits tuned to the intermediate frequency and possess satisfactory impedance characteristics. The cathode circuit is high capacitance, and the plate low capacitance. This permits a good voltage gain in the stage.

VIII. Other Applications

Most of the uses for the cathode-coupled amplifier so far mentioned operate with plate and cathode resistance. The arrangement can be used with impedances, such as tuned circuits, in these two positions. Proper application in this manner requires that the plate- and cathode-circuit impedances have the same type of frequency-impedance curves; or, in other words, the ratio of impedances of these two elements is independent of frequency. Then one has a wide-band high-frequency amplifier having a range of approximately 2 or 3 to 1 in frequency. Placing a small coupling capacitor from grounded-grid plate to cathode-follower grid on one of these amplifiers yields a basic oscillator which operates in the 100- to 200-megacycle range. This writer has had one operating on which he could connect any coil tuned between 80 and 210 megacycles and have the combination oscillate. Yet, without the input coil, no oscillation takes place. If the coil or tuned circuit placed in the grid has too high a resonant frequency, the resonant frequency of the system is that of the tuned circuit in the plate.

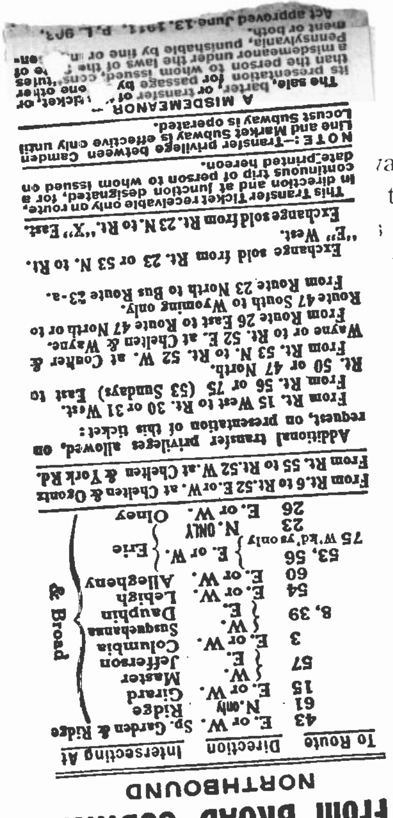
IX. Design Data

A set of curves has been taken giving the voltage gain versus cathode-resistance value for three load resistances in this amplifier. These curves are plotted as taken for a 6SN7 tube in Fig. 8. The curves can be reduced to per-unit curves applicable to any dual triode by remembering that, in the plate circuit, the comparison must be made to the plate conductance. Use of the proper scale on the amplification will make the data applicable to any dual triode of standard type. It should be noted that the greatest amplification is obtained when the cathode impedance is equal to approximately three halves of the reciprocal of the mutual conductance. Since the gain drops slowly above this value of impedance, an oscillator used with a tungsten lamp bulb in the cathode having a resistance sufficiently high will have a stabilizing action.

Using these curves on oscillators, it is necessary to assume a given input voltage on the input grid, and to adjust the plate resistance to that value which will give the voltage returned to the input grid at least slightly greater than the assumed starting voltage. Then the desired oscillation condition will develop.

In the audio oscillator, this requires a net minimum gain of 3+. This will permit establishment of oscillation if the shunt capacitances of the tube have reactances three or four times the parallel resistances.

In radio-frequency oscillators, the plate load resistance should be enough to produce a circuit gain of 4 or more. Then, as long as the reactance of the coupling capacitor is small, normal operation occurs. As long as the shunt resistance of the tuned circuit is greater than the minimum required to produce a returned unity gain, oscillation will occur. For this evaluation the tuned-circuit impedance is considered in parallel with the plate-load resistance. In practice, it is possible to make a 6SN7 tube oscillate at as high a frequency as 160



From BROAD SUBWAY

NORTHBOUND

To Route	Direction	Intersecting At
43	E. or W.	Sp. Garden & Ridge
61	N. only	Ridge & Broad
15	E. or W.	Girard & Broad
57	W. E.	Master & Broad Jefferson & Broad
3	E. or W.	Columbia & Broad
8, 39	W. E.	Susquehanna & Broad Dauphin & Broad
54	E. or W.	Lehigh & Broad
60	E. or W.	Allegheny & Broad
53, 56 75 W'kd'ys only	E. or W.	Erie & Broad
23	N. ONLY	Erie & Broad
26	E. or W.	Olney & Broad

From Rt. 6 to Rt. 52 E. or W. at Chelten & Ogontz

From Rt. 55 to Rt. 52 W. at Chelten & York Rd.

Additional transfer privileges allowed, on request, on presentation of this ticket:

From Rt. 15 West to Rt. 30 or 31 West.

From Rt. 56 or 75 (53 Sundays) East to Rt. 50 or 47 North.

From Rt. 53 N. to Rt. 52 W. at Coulter & Wayne or to Rt. 52 E. at Chelten & Wayne.

From Route 26 East to Route 47 North or to Route 47 South to Wyoming only.

From Route 23 North to Bus Route 23-a.

Exchange sold from Rt. 23 or 53 N. to Rt. "E" West.

Exchange sold from Rt. 23 N. to Rt. "X" East.

This Transfer Ticket receivable only on route, in direction and at junction designated, for a continuous trip of person to whom issued on date printed hereon.

NOTE:—Transfer privilege between Camden Line and Market Subway is effective only until Locust Subway is operated.

A MISDEMEANOR.—

The sale, barter, or transfer of [illegible] ticket, or its presentation for passage by [illegible] one other than the person to whom issued, constitutes a misdemeanor under the laws of the [illegible] of Pennsylvania, punishable by fine or [illegible]ment or both.

Act approved June 13, 1911, P. L. 903.

ay. For this experiment, the total
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a multivibrator, the same design
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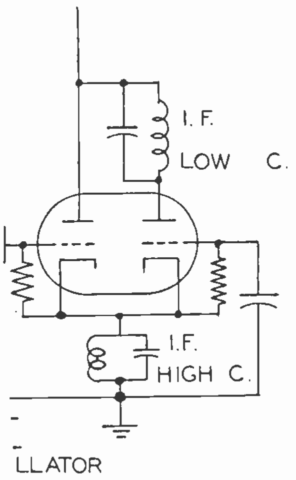

-The mixer circuit.

nce determine the frequency. As
of the tube is over 1.5, multi-
ur. The wave form is symmetrical, a unique condition for a multivibrator.

Using this unit as a wide-range amplifier, considerable care must be used if the signal amplitudes are large. The writer has found signal nonlinearity to be very troublesome under this condition.

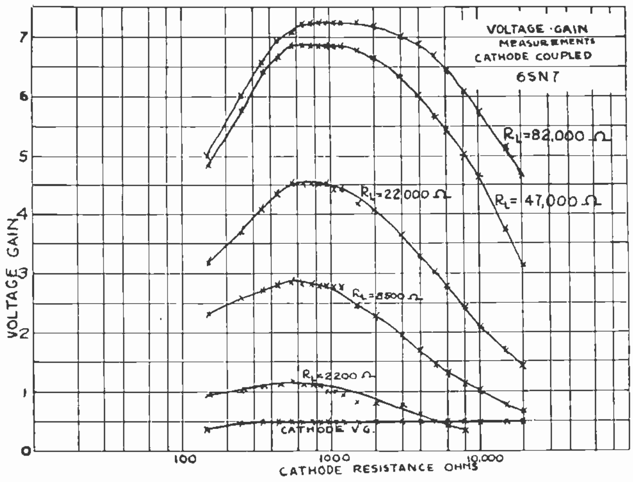

Fig. 8—Voltage-gain measurements of cathode-coupled 6SN7 tube.

X. Conclusions

As has been shown, this new cathode-coupled amplifier has an extremely wide usefulness. The methods of use are almost unlimited in scope. The writer feels that it may well become the basic circuit for almost all television, frequency-modulation, and related circuits, as well as one of the most valuable circuits for use in all types of electronic measuring equipment.

Appendix

The verification of the above-mentioned formulas for the grounded-grid amplifier is straightforward algebra. (Fig. 9). Taking the input voltage as e_i, the input current as i_1, the series impedance as Z_i, the cathode-circuit impedance as Z_k, and the plate alternating current as i_2, the first mesh equation is as follows:

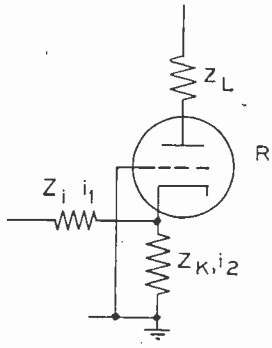

Fig. 9—Grounded grid amplifier.

$$e_i = i_1 Z_i + Z_k(i_1 + i_2).$$

Taking the plate load impedance as Z_L, the plate resistance as R_p, and the tube amplification factor as μ, the second equation is

$$[(i_1 + i_2)Z_k]\mu = i_2(Z_k + R_p + Z_L) + i_1 Z_k.$$

Solving these two for the voltage gain, which is $i_2 Z_L/e_i$, the effective amplification is

$$e_0/e_i = \mu Z_L/[Z_i(1 + \mu) + (Z_i/Z_k + 1)(R_p + Z_i)].$$

From this equation, the above facts are readily recognizable.

Likewise, the effective internal impedance of the cathode follower as a source impedance is easily obtained (Fig. 10). Here the input voltage is e, the cathode impedance is Z_k, tube plate current is i_p, plate resistance is R_p, and the amplification factor is μ. Setting up the plate-current loop, remembering the voltage on the grid is the difference between e and $i_p Z_k$, the plate current becomes

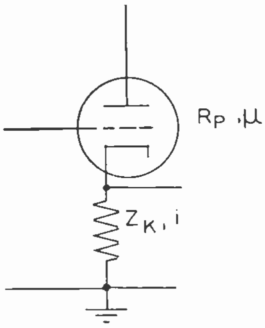

Fig. 10—Cathode follower.

$$i_p = e_i\mu/[(1 + \mu)Z_k + R_p].$$

Then subtracting voltage output from input gives circuit loss. This gives

$$e_{\text{loss}} = (Z_k + R_p)e_i/[Z_k(1 + \mu) + R_p]$$

as the voltage lost across a hypothetic series dropping resistance. Dividing this by i_p gives the expression

$$\text{loss impedance} = (Z_k + R_p)/\mu = Z_k/\mu + 1/g_m.$$

Contributors to Waves and Electrons Section

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Keats A. Pullen, Jr. (M'46) was born at Onawa, Iowa, on November 12, 1916. He received the B.S. degree from California Institute of Technology in 1939. He engaged in advanced study at Johns Hopkins University between 1939 and 1943, doing considerable teaching and independent research during this period. A number of interesting electroaccoustic developments resulted from this work. He engineered a depth-indicator unit for the Maritime Commission and a special depth indicator for the Navy while with Liberty Motors and Engineering Corporation, Baltimore, Maryland. Since 1945 he has been a special consultant in electroaccoustics and electronics in New York City. He has a number of patents under preparation. He is a member of Sigma Xi, and the American Institute of Electrical Engineers.

❖

Leonhard Katz

Leonhard Katz (M'44) was born in Vienna, Austria, on May 19, 1919. He received the B.S. degree in mechanical engineering from the Massachusetts Institute of Technology in 1941.

In 1942 he was assigned to the Radio Control Branch of the Aircraft Radio Laboratory, Wright Field, Dayton, Ohio, where he became project officer for the development and testing of airborne television and telemetering equipment. In 1944 he participated in the first airborne operations over the European Continent in which guided missiles using television equipment were employed. In 1945 he became project officer in the Radar Laboratory, Air Technical Service Command, Wright Field, and participated in a field investigation of the communications system of the German Air Force in Germany and Denmark.

He is at present employed as a development engineer at the Raytheon Manufacturing Company, Waltham, Mass.

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E. Finley Carter (A'23–F'36) was born in Elgin, Texas, on July 1, 1901. He received the B.S. degree in electrical engineering from Rice Institute in 1922, and upon graduation became associated with the General Electric Company, engaged in radio development. In 1929 he became director of the radio division of the United Research Corporation in New York City, designing radios, circuits, and receivers.

Mr. Carter joined Sylvania Electric Products, Inc., as a consulting engineer in 1932, later becoming assistant chief engineer, and in 1941, was appointed to organize and head the industrial relations department. Mr. Carter is now vice president in charge of engineering of that organization.

He is an Associate member of the American Institute of Electrical Engineers, a member of the American Radio Relay League, and of Tau Beta Pi, and was a member of the Board of Directors of The Institute of Radio Engineers in 1944 and 1945.

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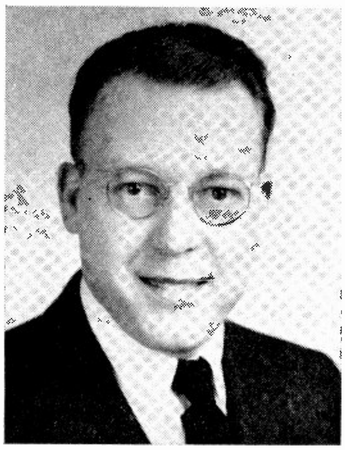
Charles J. Marshall (J'31–A'33–SM'45) was born at San Antonio, Texas, on March 27, 1912. He received the B.S. degree in electrical engineering in 1939 from the University of Cincinnati Evening College.

Mr. Marshall was employed by the Crosley Corporation as a radio technician in the test department from 1929 to 1931; as a laboratory assistant in the inspection engineering department from 1931 to 1933; as an engineer-in-charge of vacuum-tube inspection from 1933 to 1937; and was in charge of all vendor-furnished electrical parts from 1938 to 1939. In 1939 he assisted in the development and installation of the television studio and transmitter equipment of W8XCT.



Charles J. Marshall

He joined the engineering staff of the Aircraft Radio Laboratory, Signal Corps, at Wright Field, Dayton, Ohio, in 1939. From 1941 to 1943 he was project engineer for the design and testing of airborne television and telemetering equipment. From 1943 to 1944 he was chief engineer of radio-control, television, and telemetering projects. In 1945, Mr. Marshall was a development engineer on infrared equipment for the Special Projects Laboratory of the Air Service Technical Service Command. He is now chief engineer of the Special Development Branch, Aircraft Radiation Laboratory, Electronic Subdivision, Air Materièl Command, at Wright Field.

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E. Finley Carter

Abstracts and References

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ACOUSTICS AND AUDIO FREQUENCIES

534.1: 621.396.619.018.41 **1144**

Push-Pull Frequency Modulated Ciruit and Its Application to Vibratory Systems—A. Badmaieff. (*Jour. Soc. Mot. Pict. Eng.*, vol. 46, pp. 37–51; January, 1946.) A circuit in which the push-pull action is accomplished by using two capacitors with a common plate to vary the resonant frequencies of oscillator and discriminator in opposite phase relation. This circuit can be used for measuring vibrations or for monitoring purposes if the common plate is the moving element of a vibratory system. For application to the calibration of gramophone recording heads, see 3548 of 1945 (Roys).

534.121.1 **1145**

The Fundamental Frequency of Vibration of Rectangular Wood and Plywood Plates—R. F. S. Hearmon. (*Proc. Phys. Soc.*, vol. 58, pp. 78–92; January, 1946.) Results of theoretical and experimental investigation.

534.321.9 **1146**

Ultrasonic Interference at Angular Reflection—G. W. Willard. (*Phys. Rev.*, vol. 68, p. 284; December 1–15, 1945.) Abstract of an American Physical Society paper.

534.321.9: 538.652 **1147**

Magnetostrictive Oscillator Coupling—H. Thiede. (*Elec. Ind.*, vol. 5, p. 96; January, 1946.) A piston coupler of ceramic allows the application of a magnetostrictive oscillator under circumstances beyond its normal operative range, such as ultrasonic excitation of liquids (acids or bases) up to 700 degrees centigrade. Abstract of a paper in *Akus. Zeit.*, vol. 8, no. 1.

534.321.9: 620.179 **1148**

Supersonic Flaw Detector—R. B. De Lano, Jr. (*Electronics*, vol. 19, pp. 132–136; January, 1946.) The radar principle of pulse reflection from discontinuities is used with longitudinal supersonic waves of frequency 0.5 to 12 megacycles per second. Pulses, a few microseconds long, and with a 60-cycle-per-second repetition rate, are applied by a quartz-crystal transducer to the material under test, efficient coupling being obtained by a film of liquid. The same crystal serves as a pickup for the reflected pulse, which is amplified and displayed on a cathode-ray tube with an exponential time base and time marks, enabling the depth of the discontinuity to be measured.

The supersonic characteristics of various materials and pictorial examples of the performance of the instrument are given. See also 822 of April (Firestone).

534.321.9: 620.179 **1149**

Ultrasonic Vibrations Reveal Hidden Flaws—(*Elec. Ind.*, vol. 5, pp. 64–166; January, 1946.) Supersonic waves (50 kilocycles per second to 1 megacycle per second) are transmitted from a crystal vibrator to a crystal microphone through a moving strip or sheet to be tested. A flaw causes a change in attenuation, and the change in the received signal actuates a relay. The arrangement is useful for examining extruded products.

534.41 + 534.781 **1150**

Visible Speech Patterns Transmit Intelligence—(*Electronics*, vol. 19, pp. 200–202; January, 1946.) A short account of 823 of April (Potter).

534.42 **1151**

Electronic Sound Effects Circuit—H. Syzling. (*Electronics*, vol. 19, pp. 214–220; January, 1946.) Description of a battle-sound generator giving an output of 200 watts with automatic operation. Circuits for generating the sounds of near and distant shell bursts, machine guns, etc., are briefly described.

534.43: 621.395.61 **1152**

FM Phonograph Reproducer—W. Hausz. (*Elec. Ind.*, vol. 5, p. 106; February, 1946.) A capacitive pickup unit. The needle vibrations vary the frequencies of two high-frequency oscillators in push-pull, and the frequency-modulated difference frequency is filtered and detected. The mechanical design reduces the effects of eccentric records. Summary of U.S. Patent 2,386,049.

534.43: 621.395.61 **1153**

New Vibrating Reed Magnetic Pickup—R. G. Leitner. (*Radio*, vol. 29, pp. 25–63; December, 1945.) Design and construction. Output 2.5 millivolts at 1000 cycles per second. Cutoff 6000 cycles per second, but a special broadcast model cuts off at 12,000 cycles per second.

534.43: 621.395.61 **1154**

[Gramophone] Pickup with Low Mechanical Impedance—H. P. Kalmus. (*Electronics*, vol. 19, pp. 140–145; January, 1946.) Amplitude modulation of a 2.5-megacycle-per-second oscillator is produced by the motion of a resistive vane which is coupled to the stylus and varies the *Q* of the oscillator circuit. The triode oscillator acts simultaneously as a detector and audio-frequency amplifier. High compliance and small mass of moving element result in low mechanical impedance, so that only 14 grams weight is needed for satisfactory tracking. The response falls sharply at 4000 to 5000 cycles per second.

534.845: 534.373 **1155**

The Application of the Helmholtz Resonator to the Measurement of Sound Absorption—W. S. Tucker. (*Phil. Mag.*, vol. 36, pp. 473–485; July, 1945.) The resonance curve of a Helmholtz resonator excited by a sound field depends on, among other factors, the absorbing power of its walls. In the experiments described this fact was utilized to determine the absorbing power of porous earthenware over the range 150 to 600 cycles per second. A hot-wire (Tucker) microphone, located in the open mouth of the resonator, was used as the detector.

534.845: 677.521. **1156**

A Discussion of the Acoustical Properties of Fiberglas—W. M. Rees and R. B. Taylor. (*Jour. Soc. Mot. Pic. Eng.*, vol. 46, pp. 52–63; January, 1946.) The absorbing properties are discussed, with particular reference to aircraft sound insulation. Absorption tables for frequencies up to 4000 cycles per second are given.

534.862.6 **1157**

Intermodulation Distortion of Low Frequencies in Sound Film Recording—F. G. Albin. (*Jour. Soc. Mot. Pic. Eng.*, vol. 46, pp. 4–16; January, 1946.) An account of the phenomenon in variable-density recording, due to the photographic process.

537.228.1 1158
The Order of Magnitude of Piezoelectric Effects—Jaffe. (*See* 1264.)

621.395.6 1159
War Influence on Acoustic Trends—H. S. Knowles. (*Elec. Ind.*, vol. 4, pp. 81, 192; December, 1945.) An account of some of the special measures needed to transmit intelligence through the very high noise levels of battle conditions. Summary of an Institute of Radio Engineers paper. See also *Electronics*, vol. 19, pp. 246–248; January, 1946.

621.395.613.37 1160
Antinoise Characteristics of Differential Microphones—H. E. Ellithorn and A. M. Wiggins. (Proc. I.R.E., and Waves and Electrons, vol. 34, pp. 84P–89P; February, 1946.) The noise discrimination is obtained as a function of frequency and pressure-gradient for both practical and theoretical microphones. It is shown that the differential microphone is ideally suited for noise cancellation in the usual noise fields, in which the frequencies are often predominantly in the lower frequency range. The noise discrimination increases rapidly with the order of the pressure gradient upon which the microphone operates, but the use of high-order gradients presents constructional difficulties. The noise discrimination of the *n*th-order gradient is derived.

621.395.613.4 1161
Dynamic Microphone—W. Baer. (*Elec. Ind.*, vol. 5, p. 99; February, 1946.) Illustrated description of the design of a moving-coil microphone. Air pockets behind the diaphragm give resonances at 450, 2500, and 8000 cycles per second, and thereby give high sensitivity and comparatively level frequency response. Diagrams illustrate the directional properties. The sensitivity is at least 100 microvolts per dyne per centimeter^{-2} for an output resistance of 200 ohms at 800 cycles per second. Over-all efficiency 0.4 per cent. Summary of a paper in *Akus. Zeit.*, vol. 8, No. 4.

621.395.623.8 1162
Improved Sound Reproducer—C. A. Volf. (*Radio News*, vol. 35, pp. 38–100; January, 1946.) General description of the system referred to in 531 of March.

621.395.623.8 1163
Psychological and Technical Considerations Employed in the Bucky Sound Reproduction and Public Address Systems—P. A. Bucky. (*Jour. Soc. Mot. Pic. Eng.*, vol. 46, pp. 75–79; January, 1946.) Reactions of the physical senses to musical sounds are discussed. Replacement of conventional highly directive theater or auditorium loudspeakers by another system with nondirectional characteristics is suggested. Reverberation from several speakers replaces the original sound picture, and a radio-frequency carrier is used for signal distribution.

621.395.625.3 1164
High Quality Sound Recording on Magnetic Wire—L. C. Holmes. (*Electronics*, vol. 19, pp. 236–240; January, 1946.) Another report of the Institute of Radio Engineers paper. See also 836 of April.

621.395.645+621.396.61/.62 1165
Low Power Transmitting, Receiving, and Hailing Equipment. Type CNY. 1—Morcom. (*See* 1386.)

621.395.645.3 1166
An Analysis of the Comparison of Beam Power and Triode Tubes Used in Power Amplifiers for Driving Loudspeakers—J. K. Hilliard. (*Jour. Soc. Mot. Pic. Eng.*, vol. 46, pp. 30–36; January, 1946.) The beam-power tube is equally efficient with the same or less distortion, has an improved signal-to-noise ratio, and the associated circuit need not be complicated. Excellent output transformers are required. Results of listener and objective tests.

621.395.645.3 1167
Bridging [A-F] Amplifier for F-M Monitoring—Beggs. (*See* 1199.)

621.395.645.36 1168
Quality Amplifiers—(*Wireless World*, vol. 52, p. 61; February, 1946.) Correction to a circuit in 838 of April.

621.395.665. 1169
Mixing Crystal Microphones—G. N. Patchett. (*Wireless World*, vol. 52, pp. 57–58; February, 1946.) The difficulty of providing high-impedance inputs and adequate volume control, when it is required to mix the outputs from two or more crystal microphones, is overcome by using heptodes with a common anode load. Each microphone output is connected separately to the control grid of a heptode of which the amplication is controlled by the bias of its third grid.

621.395.667. 1170
A Three-Band Variable Equalizer—L. D. Grignon. (*Jour. Soc. Mot. Pic. Eng.*, vol. 46, pp. 64–74; January, 1946.) Provides suppression and emphasis in three frequency bands, adjustable by three controls. The features include zero insertion loss, and small change in apparent insertion loss as equalization is varied.

621.396.611.21.029.3+621.317.761 1171
Stabilizing Frequency in LF [1–10 kc/s] Crystal Oscillators—Cox. (*See* 1294.)

AERIALS AND TRANSMISSION LINES

621.392 1172
Contribution to the Theory of Telephone Cables with Twisted Conductor Groups—C. G. Aurell. (*Ericsson Technics*, no. 45, p. 3; 1944.) The transmission properties are developed along the same lines as for a system of parallel homogeneous conductors. Explicit formulas for the propagation constants and characteristic impedances for the conductors of such groups are deduced. The analysis is applied to the cross-talk problem.

621.392 1173
The Solution of Transmission-Line Problems in the Case of Attenuating Transmission Line—G. Glinski. (*Trans. A.I.E.E.*, (*Elec. Eng.*, February, 1946), vol. 65, pp. 46–48; February, 1946.) Demonstration of how "by application of the standard transmission-line theory the standing-wave method of measuring impedance can be extended to the case of transmission lines with attenuation, if the appropriate corrections are introduced." The paper assembles and systematizes information on the subject in other literature.

621.392 1174
Discontinuity Effects—G. Glinski. (*Elec. Ind.*, vol. 5, pp. 97–98; February, 1946.) The effect of a discontinuity in a transmission line is determined by locating the voltage minimum on each side of it. For a coaxial line, the position of the voltage minimum on one side of a discontinuity is graphed versus the position of a short circuit on the other side and the diagram is interpreted.

621.392 1175
Minimum Attenuation in Waveguides—E. N. Phillips. (*Electronics*, vol. 19, pp. 137–139; January, 1946.) Algebraic and graphical presentation of the attenuation in rectangular and circular wave guides for various modes of propagation. The ratio of the frequency of minimum attenuation (f_{min}) to the cut-off frequency (f_c) for H modes in a rectangular guide is derived as a function of the ratio a/b of the sides, and the mode numbers n, m. For E modes, $f_{min} = \sqrt{3} f_c$. The attenuation of an $H_{0,1}$ wave in a typical rectangular brass guide is evaluated by way of illustration, and compared with brass concentric lines of the same cross-section area or the same periphery.

621.392: 621.396.67 1176
Aerial Resistance and Cable Impedance—G. W. O. H. (*Wireless Eng.*, vol. 23, pp. 65–66; March, 1946.) The approximate equality of the radiation resistance of a half-wave dipole in free space to the characteristic impedance of a coaxial cable, with conductor diameter ratio giving minimum attenuation loss, is shown to be coincidental.

621.392: 621.396.692 1177
Radio-Frequency Resistors as Uniform Transmission Lines—D. R. Crosby and C. H. Pennypacker. (Proc. I.R.E. and Waves and Electrons, vol. 34, pp. 62P–66P; February, 1946.) A theoretical analysis, using the classical transmission-line equations, of concentric lines with resistive inner conductors, the resistance being in the form of a film so that skin effect is negligible. The resistive element is long compared with the diameter of the outer conductor. The case where the resistor is intended to match a coaxial line is given particular attention, and the results are presented in a number of graphs which should be convenient for engineering use.

621.392.43 1178
Shunt and Series Sections of Transmission Line for Impedance Matching—C. T. Tai. (*Jour. Appl. Phys.*, vol. 17, pp. 44–50; January, 1946.) Expressing the terminal impedance to be matched as a hyperbolic function enables the matching conditions of both series and shunt sections to be simply expressed in terms of the resistance and reactance of the load and the characteristic impedance of the line. A graphical representation of the solutions shows that matching for each case is only possible inside certain areas bounded by a circle and straight line on a graph of load resistance against load reactance. The series section permits matching over a wider range of impedances than the shunt section, but the latter is useful

in the region where the series section cannot yield a match. If an additional section of line is added between the matching section and the load, then both sections can be made to match any load.

621.396.11+621.396.82 **1179**

Notes on the Reception of Vertically Polarized Electromagnetic Waves; Some Notes on Circuit Shielding—(*Radio*, vol. 29, pp. 39–40; December, 1945.) A radio design work sheet.

621.396.67 **1180**

Three New Antenna Types and Their Applications—A. G. Kandoian. (PROC. I.R.E. AND WAVES AND ELECTRONS, vol. 1, pp. 70W–75W; February, 1946.) All are primarily for very-high-frequency and ultra-high-frequency operation. Their radiation is substantially omnidirectional in the horizontal plane. A disk and cone type has a high-pass cutoff frequency above which the input impedance varies little over a 5:1 frequency range. A coaxially fed horizontal loop ("magnetic dipole") can be designed to match a coaxial line of, *e.g.*, 50-, 70-, 100-ohm characteristic impedance at a particular frequency. An "electric-magnetic dipole" consisting of a coaxially fed horizontal loop with a vertical radiator rising from its center gives an elliptically polarized field distributed roughly as for an ordinary $\lambda/2$ dipole. It may be useful for counteracting severe fading conditions, when vertical and horizontal field components will probably not vary at the same rate. Constructional details of all types are shown, and the applications, singly and in multiple arrays, are discussed.

621.396.67 **1181**

Remote Tuned Antenna—(*Elec. Ind.*, vol. 5, p. 77; February, 1946.) A motor operates the telescopic arms of a rotatable horizontal dipole, to cover a range 46.5 to 215 megacycles per second.

621.396.67 **1182**

Currents in Aerials and High-Frequency Networks [Book Review]—F. B. Pidduck. Oxford University Press, London, England, 8s. 6d. (*Wireless Eng.*, vol. 23, p. 90; March, 1946.) "The book is of an ultramathematical character."

CIRCUITS

621.3.011.2.012 **1183**

Impedance-Admittance Conversion Chart—R. C. Paine. (*Electronics*, vol. 19, p. 162; January, 1946.) Simple chart for converting $Z=R\pm jX$ to $Y=G\mp jB$ and *vice versa*.

621.3.017: 621.3.012.3. **1184**

Loss Due to Shunt Resistance Inserted Between Matched Source and Sink—(*Radio*, vol. 29, p. 37; December, 1945.) A design chart.

621.314.12 **1185**

D.C. Amplifier Coupling—P. K. Chatterjea and C. T. Scully. (*Elec. Ind.*, vol. 5, p. 118; January, 1946.) The use of a nonlinear resistance element, such as a thermistor, permits the transmission of a large proportion of a voltage change from an anode to a grid, without transmitting a corresponding proportion of the mean anode potential. Summary of U.S. Patent 2,383,710.

621.318.572: 621.385.38 **1186**

Pulse Response of Thyratron Grid-Control Circuits—C. H. Gleason and C. Beckman. (PROC. I.R.E. AND WAVES AND ELECTRONS, vol. 34, pp. 71P–77P; February, 1946.) Advantages of peaked-wave-form grid signals are discussed, and graphs given from which the influence of grid-circuit components on the grid-potential wave form can be predicted for several commonly used signal wave forms. The analysis is based on the assumption that the thyratron presents a relatively high impedance to the grid circuit, and the effect of grid current during the period prior to the initiation of the discharge is examined. In many cases the grid current is reasonably constant over a considerable range of negative grid voltage, and the correction required to take account of it amounts to a shift in the direct-current bias value.

621.385.2/.5].012.8 **1187**

Valve Equivalent Circuit—H. Biefer. (*Wireless Eng.*, vol. 23, pp. 91–92; March, 1946.) In vacuum-tube-circuit analysis, ambiguity can be avoided in the derivation of an equivalent circuit by attaching a definite sign to both current and voltage symbols. Comment on 3505 of 1945 (G.W.O.H.).

621.392.52 **1188**

Transient Response of Filters [Part II]—D. G. Tucker. (*Wireless Eng.*, vol. 23, pp. 84–90; March, 1946.) The method given in part I (870 of April) for the analysis of the transient response of multistage filters is inapplicable to single-section filters, and a new method of approach, using operational methods, is given. The build-up and decay envelopes of a single-section filter, used between resistance terminations equal to its design resistance, are analyzed, and the results compared with oscillographic records. The effects of slight variations in signal frequency are determined empirically by oscillographic methods.

621.394/.397].645 **1189**

Cathode-Follower Dangers: Output Circuit Capacitance—W. T. Cocking. (*Wireless World*, vol. 52, pp. 79–82; March, 1946.) It is shown that the particular advantages of the cathode-follower circuit are not maintained at frequencies so high that the time constant of the cathode circuit becomes significant. Very great care is needed in the design of cathode-follower circuits for television and radar frequencies, because the feedback feature accentuates the distortion effect of this time constant on pulse shape, and the effects of momentary cutoff of anode current by excessive input. ". . . so far from the cathode follower being able, by virtue of its low output resistance, to feed a circuit of high capacitance, it is usually necessary to restrict the capacitance to the lowest possible value."

621.394/.397].645.2 **1190**

Wide-Band Amplifiers—1.. Single-Circuit RF and IF Couplings: Coincidence Tuning—(*Wireless World*, vol. 52, pp. 90–92; March, 1946.) General principles and detailed design formulas for wide-band couplings consisting of two circuits individually tuned to the same frequency.

621.394/.397].645: 621.396.822 **1191**

Noise Factor of Valve Amplifiers—N. R. Campbell, V. J. Francis, and E. G. James. (*Wireless Eng.*, vol. 23, pp. 74–83; March, 1946.) Conclusions of earlier papers are restated and applied to the design of vacuum-tube amplifiers. General formulas for the noise and gain of an amplifier stage are used to derive particular formulas for the common-grid triode and the common-cathode pentode, account being taken of lead inductances and interelectrode capacitances. Properties of perfect and dissipative four-terminal passive networks are discussed. The results are used to determine the effect on signal-to-noise ratio of the addition of extra stages to a cascade amplifier. The first of two parts. See also 1037 of April (Campbell and Francis) and 2918 of 1945 (Campbell, Francis, and James).

621.394/.397].645.3 **1192**

Negative Feedback—1. "Cathode Ray"—(*Wireless World*, vol. 52, pp. 41–44; February, 1946.) A simple explanation of the principle of negative feedback in amplifiers, dealing particularly with the difference between current and voltage feedback and their effects on the apparent internal resistance of the vacuum tube, considered in relation to the output load. For part 2, see 1193.

621.394/.397].645.3 **1193**

Negative Feedback—2. Its Effect on Optimum Load and on Distortion—"Cathode Ray"—(*Wireless World*, vol. 52, pp. 76–78; March, 1946.) For part 1 see 1192. The present article gives a graphical demonstration of the reduction of distortion by negative feedback, and explains why the best load resistance does not differ materially from that appropriate to the same vacuum tube without feedback.

621.394/.397].645.3: 621.314.25 **1194**

Phase-Inverter Circuit—C. B. Fisher and D. L. Drukey. PROC. I.R.E. AND WAVES AND ELECTRONS, vol. 34, p. 92P; February, 1946.) An application of the circuit described by Drukey (3846 of 1945). A high degree of balance and independence of tube characteristics is obtained, together with suppression of hum, tube noise, or distortion produced in the driver stage. A circuit diagram is given with component values.

621.394/.397].645.3: 621.314.25 **1195**

An Analysis of Three Self-Balancing Phase Inverters—M. S. Wheeler. (PROC. I.R.E. AND WAVES AND ELECTRONS, vol. 34, pp. 67P–70P; February, 1946.) "A self-balancing phase inverter is a circuit converting one driving voltage to two output voltages of opposite phase but of essentially equal magnitude by an inherent characteristic of the device and not by virtue of any critical adjustment. The algebraic solution of three self-balancing phase inverters is given, assuming all circuit elements are linear. Included in the solution are the conditions for self-balance, the balance ratio, and the voltage gain. From this information, the type of inverter for a particular service may be selected and designed."

621.395.44: 621.395.645. **1196**

Carrier-Frequency Amplifiers: Transient Response with De-tuned Carrier—C. C.

Eaglesfield. (*Wireless Eng.*, vol. 23, pp. 67–74; March, 1946.) An analysis by operational methods of the transient response of an amplifier whose central frequency may differ from the carrier frequency. The importance of the depth of modulation of the the test input wave form is investigated, and reasons are given for making it small. Numerical solutions are given for typical arrangements of a chain of eight stages. See also 68 of January (Eaglesfield).

621.395.645.29 **1197**

A Cathode-Coupled [a.f.] **Isolating Amplifier**—E. Travis. (*Electronics*, vol. 19, pp. 202–204; January, 1946.)

621.395.645.3 **1198**

An Analysis of the Comparison of Beam Power and Triode Tubes Used in Power Amplifiers for Driving Loudspeakers—Hilliard. (*See* 1166.)

621.395.645.3 **1199**

Bridging Amplifier for F-M Monitoring—G. E. Beggs, Jr. (*Electronics*, vol. 19, pp. 152–155; January, 1946.) The amplifier uses push-pull triodes throughout. The input stage is followed by a driver with a five-step gain control. Transformer coupling to the output stage is used, with negative feedback from output anodes to driver cathodes. A uniform response within ±0.5 decibel, with 15 watts output for 0.3 volt root-mean-square input is obtained over the frequency range 20 cycles per second to 25 kilocycles per second, and the signal-to-noise ratio at maximum output is about 80 decibels. The amplifier is designed for use with a balanced input but may be used with a single-ended input by earthing the unused grid.

621.395.645.36 **1200**

Quality Amplifiers—(*Wireless World*, vol. 52, p. 61; February, 1946.) Correction to a circuit in 838 of April.

621.395.665 **1201**

Mixing Crystal Microphones—Patchett. (*See* 1169.)

621.396.11+621.396.82 **1202**

Notes on the Reception of Vertically Polarized Electromagnetic Waves; Some Notes on Circuit Shielding—(*Radio*, vol. 29, pp. 39–40; December, 1945.) A radio design work sheet.

621.396.611.1 **1203**

The Series and Parallel Components of Impedance—W. N. Tuttle. (*Gen. Rad. Exp.*, vol. 20, pp. 1–3; January, 1946.) Equations relating the series and parallel components of an impedance are applied to the case of parallel resonant circuits with high coil losses.

621.396.611.1.012.3 **1204**

Nomogram for Frequency Formula [$f=1/(2\pi\sqrt{LC})$]—C. P. Nachod. (*Elec. Eng. N. Y.*, vol. 64, p. 469; December, 1945.)

621.396.611.21 **1205**

Electrodynamic Theory of Piezoelectric Oscillations—W. F. G. Swann. (*Phys. Rev.*, vol. 68, p. 282; December 1–15, 1945.) The problem is that of an X-cut crystal with self-induction and resistance in series, and vibrating with its two ends in different media. It is solved on the basis of Maxwell's general dynamical theory. Abstract of an American Physical Society paper.

621.396.611.21: 621.396.662.34 **1206**

Crystal Filter Theory—F. J. Lehany and K. G. Dean. (*Radio*, vol. 29, pp. 8, 16; December, 1945.) Illustrated summary of 3820 of 1945.

621.396.615 **1207**

A New Type of Electrical Resonance—E. E. Schneider. (*Phil. Mag.*, vol. 36, pp. 371–392; June, 1945.) Utilization of phase inversion in a vacuum tube leads to a method of obtaining resonance with circuits containing only resistance and capacitance or resistance and inductance. Such circuits are compared with known resistance-capacitance oscillatory circuits, and the properties of reactance vacuum-tube networks are discussed and analyzed in detail. Experimental response curves are given for single and coupled resistance-capacitance circuits at very low frequencies.

621.396.615.14.029.62/.63 **1208**

Asymmetrical Butterfly Circuit—A. Landman. (PROC. I.R.E. AND WAVES AND ELECTRONS, vol. 34, p. 92P; February, 1946.) A circuit of good stability, using an RL 16 tube. The frequency range of the oscillator is restricted, in this case, to 290 to 350 megacycles per second. See also 3260 of 1945 (Karplus) and 1209.

621.396.615.14.029.63 **1209**

Coaxial Modification of the Butterfly Circuit—E. E. Gross. (*Electronics*, vol. 19, pp. 222–226; January, 1946.) Another abstract of the Institute of Radio Engineers paper; see also 883 of April.

621.396.615.17 **1210**

A New Pulse Generator Circuit—B. M. Banerjee. (*Indian Jour. Phys.*, vol. 19, pp. 75–82; June, 1945.) For many purposes, in particular for testing Geiger-Müller tube circuits, accurate synchronization between a pulse generator and a cathode-ray-tube time base is needed. This is achieved by the generation of a separately available synchronizing pulse preceding the main pulse by a fixed time interval. The assembly has three main parts—an unsymmetrical multivibrator, a pair of pulse-generating networks, and a pair of pulse amplifiers biased beyond cutoff. The performance of the particular model described is: pulse repetition frequency, 2 cycles per second to 200 kilocycles per second; pulse separation, 2 microseconds to 0.25 second; pulse durations, main 1 microsecond to 100 microseconds; synchronization, 1 microsecond to 500 microseconds. These are all independently variable. The generator produces negative pulses, triangular, 12 volts peak. It is claimed that the generator is "a simple solution of all the radio sounding problems associated with ionospheric apparatus. It is therefore expected that it will find wide use in this field."

621.396.615.17: 621.384.6 **1211**

Betatron Pulsing System—I. Paul and T. J. Wang. (*Electronics*, vol. 19, pp. 156–160; January, 1946.) A circuit is described for producing high-power pulses for the orbit-shift coils of a betatron; it has other applications, e.g., resistance welding and stroboscopic illumination.

A square-wave generator obtained from the sinusoidal voltage of the betatron coils is followed by a differentiator and flip-flop pulse amplifier producing a positive pulse of about 70 volts amplitude. This is used to trigger a thyratron, which, suddenly discharging, fires an ignitron, which discharges a 60-microfarad capacitor through the orbit-shift coils, giving a 1000-amperes peak pulse, about 40 microseconds long at half amplitude.

621.396.615.17: 621.397.3 **1212**

Television Sweep Oscillators—Noll. (*See* 1381.)

621.396.619.018.41: 534.1 **1213**

Push-Pull Frequency Modulated Circuit and Its Application to Vibratory Systems—Badmaieff. (*See* 1144.)

621.396.66 **1214**

Control and Recording with Floating Grid—E. L. Deeter. (*Electronics*, vol. 19, pp. 172–198; January, 1946.) A large alternating voltage is applied through a very small capacitance (about 0.2 micromicrofarad) to the top cap grid of a vacuum tube, normal grid leakage being avoided as far as possible. With a suitable voltage, the capacitance provides a sensitive control of the anode current, which may be made to work a relay or recorder.

621.38 **1215**

Electronics for Engineers [Book Review]—Markus and Zeluff. (*See* 1428.)

621.392: 621.3.015.33 **1216**

Pulsed Linear Networks [Book Review]—E. Frank. McGraw-Hill Book Co., New York, N. Y., 1945, 262 pp., $3.00. (*Electronics*, vol. 19, pp. 348–350; January, 1946.) See also 582 of March.

GENERAL PHYSICS

530.12: 531.18 **1217**

Derivation of the Lorentz Transformations—H. E. Ives. (*Phil. Mag.*, vol. 36, pp. 392–403; June, 1945.) New derivation shows that the transformations can be obtained by imposing the laws of conservation of energy and momentum on radiation processes as developed by Maxwell's method. The solution of apparent conflicts demands the variation of mass with velocity, and the variation of linear dimensions and clock rate. The space and time concepts of Newton and Maxwell are retained without alteration.

530.12: 538.3 **1218**

Relativistic Interaction of Electrons on Podolsky's Generalized Quantum Electrodynamics—D. J. Montgomery. (*Phys. Rev.*, vol. 68, p. 287; December 1–15, 1945.) Extension of the basis for a generalized electrodynamics involving higher derivatives in the field equations formulated by Podolsky and Kikuchi (*Phys. Rev.*, 1944, vol. 65, p. 228, and 1945, vol. 67, p. 184). Results are applied to the relativistic interaction of two electrons. Abstract of an American Physical Society paper.

531.4+539.62+621.394.653+621.395.653 **1219**

The Physics of Rubbing Surfaces—F. P. Bowden. (*Jour. Roy. Soc. N.S.W.*, vol. 78, pp. 187–219; December 3, 1945.) A comprehensive review of experimental information on the mechanism of frictional forces. The area of true contact is only a very small fraction ($\sim 10^{-4}$) of the total area of the apparently touching surfaces. The electrical conductance between two given materials is independent of the area of the apparently touching surfaces, and is little affected by their state of roughness; it depends mainly on the mechanical force between them. The deformation of the material at the points of true contact is mainly plastic rather than elastic.

The temperature at the true contact points when metals are rubbed together depends on load, speed of sliding, and thermal conductance, but can be very high. Polishing is mainly caused by melting at the contact points. A material with a high melting or softening point will polish a material that has a lower melting or softening point. The relative hardnesses at room temperature are unimportant.

Friction and surface damage of metals sliding very slowly so that contact temperature rise is not great depends on the relative hardnesses. The surface of the softer metal of a pair is ploughed out and torn; the harder surface is comparatively undamaged, but fragments of the softer metal are welded on to it; the damage to rubbing surfaces of similar homogeneous metals is more profound. Work hardening and deformation of rubbing metals occurs to a considerable depth below the actual track of the contact.

The theory of solid friction is examined. The use of metallic films as lubricants and the use of bearing alloys are discussed. The effect of naturally occurring films of oxide and other impurities on the reduction of friction between metal surfaces is shown to be very large.

534+538.56 **1220**

The Wave Equation in a Medium With a [Space-] Variable Index of Refraction—P. G. Bergmann. (*Phys. Rev.*, vol. 68, p. 286; December 1–15, 1945.) Abstract of an American Physical Society paper.

535.317: 621. 397 **1221**

[Optical] Lens Aberrations in Picture Projection—Montani. (*See* 1379.)

535.43 **1222**

On the Theory of Light-Scattering—A Note—S. Parthasarathy. (*Phil. Mag.*, vol. 36, pp. 510–514; July, 1945.) A continuation of an argument with Krishnan (see 3334 of 1940). The writer claims that Krishnan's results "have been vitiated by grave errors" and gives detailed reasons.

537.221: 621.317.32 **1223**

A Modified Kelvin Method for Measuring Contact Potential Differences—Meyerhof and Miller. (*See* 1282.)

537.525 **1224**

Small Perturbations of the Electric Discharge—V. L. Granovsky. (*C. R. Acad. Sci. U.S.S.R.*, vol. 28, pp. 40–44; July 10, 1940. In English.) Equations were developed in a previous paper (*C. R. Acad. Sci. U.S.S.R.*, vol. 26, no. 9—Granovsky) describing the dynamic states of the plasma under diffusion conditions. In this paper conclusions are deduced from them for conditions of small perturbations. (a) The relations between the variable components of the discharge parameters do not depend on the external circuit. (b) The passage of a transient is aperiodic for gas pressures greater than a critical value, and damped oscillatory for lower pressures. (c) Forced oscillations (modulated discharge) are considered, and various semiquantitative conclusions reached on the relationship between the modulating electromotive force and the current, particle concentration, etc.

537.531(091) **1225**

X-Rays, an Early Institute Topic—(*Elec. Eng.*, vol. 64, pp. 435–436; December, 1945.) Excerpts from papers delivered before the American Institute of Electrical Engineers in 1896 on theoretical and practical aspects of X rays.

537.533.8 **1226**

Erratum: Secondary Emission of Pyrex Glass—C. W. Mueller. (*Jour. Appl. Phys.*, vol. 17, p. 62; January, 1946.) Correction to the composition of the glass quoted in 3648 of 1945.

538.1 **1227**

Note on Magnetic Energy—E. A. Guggenheim. (*Phys. Rev.*, vol. 68, pp. 273–276; December 1–15, 1945.) A note to correlate the magnetic-energy equations obtained by Livens (2825 of 1945) with the author's previous results (3221 of 1936). These equations apply to any unique relation between B and H whereas those of Livens are based on "linear laws of induction." In the two cases considered by Livens, it is shown that the formulas only differ from the author's by constants.

538.569.4+621.396.11.029.64 **1228**

The Absorption of Microwaves by Gases—Hershberger. (*See* 1336.)

539.16.08 **1229**

Counters for Use in Nuclear Spectroscopy—M. L. Wiedenbeck. (*Rev. Sci. Instr.*, vol. 17, pp. 35–37; January, 1946.) A description of several self-quenching counters for counting conversion electrons with energies as low as 20,000 electron volts arising from an excitation process having a cross section of the order of 10^{-34} square centimeters.

539.16.08: 621.385.5 **1230**

Use of 6AK5 and 954 Tubes in Ionization Chamber Pulse Amplifiers—Parsegian. (*See* 1404.)

539.163.2.08 **1231**

The Theory of the 180° Magnetic Focusing Type of Beta Ray Spectrometer—A. K. Saha. (*Indian Jour. Phys.*, vol. 19, pp. 97–119; June, 1945. Development of an expression for the transmission factor as a function of the magnetic field and the electron momentum. It is illustrated by the complete calculation of the factor for the Lawson and Tyler spectrometer.

621.385.833 **1232**

Space-Charge-Limited Beams in Electrostatic Fields—Rose. (*See* 1313).

5 **1233**

Science in Progress. Fourth Series [Book Review]—University Press, Yale, Oxford University Press, London, 331 pp., $3.00. (*Proc. Phys. Soc.*, vol. 58. pp. 129–130; January 1, 1946.) A set of eleven essays by eminent scientists, including one by Rabi on molecular beams and radio-frequency spectroscopy.

530.145.6 **1234**

Elementary Wave Mechanics [Book Review]—W. Heitler. Oxford University Press, London, 1945, 136 pp., 7s.6d. (*Proc. Phys. Soc.*, vol. 58, pp. 127–128; January 1, 1946.) "It is truly elementary, both in the demands which it makes on the previous knowledge and mathematical ability of the reader, and also in that it deals only with the elements of wave mechanics."

GEOPHYSICAL AND EXTRA-TERRESTRIAL PHENOMENA

523.746.5: 621.396.11: 551.51.053.5 **1235**

The New Sunspot Cycle—T. W. Bennington. (*Wireless World*, vol. 52, pp. 83–85; March, 1946.) The rise in the sunspot number from its minimum in 1944 has been unusually rapid. The next maximum may be considerably higher than the last. It may occur before May, 1948, or in 1949. The curves of 12-month running averages of sunspot numbers and of critical frequency show a remarkable parallelism and should enable the prediction of the long-period variation of these quantities for a short time ahead with great accuracy. The article gives very detailed anticipation of usable frequencies for various routes: e.g., "Frequencies up to 22 megacycles per second ought to be usable for good periods during the day in the early months [of 1946] for communication with the United States of America, falling to about 17 megacycles per second during the summer and increasing to about 29 megacycles per second next winter. When all the path is in darkness, 7 megacycles per second will at first be the highest safe frequency, but next summer frequencies up to 14 megacycles per second should be usable most of the night. By next winter 10 megacycles may be usable throughout the night."

550.38+551.594.5 **1236**

The Aurora and Geomagnetism—C. W. Gartlein. (*Elec. Ind.*, vol. 4, pp. 76–77; December, 1945.) An electron device now under development is expected to overcome the difficulty of observing weak auroral activity during the full-moon period. Closer correlation between solar and magnetic intensity observations is foreseen. A brief survey of the relation between sunspots and magnetic storms produced by currents in the upper atmosphere and their effect on communications. Summary of an Institute of Radio Engineers paper. See also *Electronics*, Janvary, 1946, vol. 19, pp. 242–244.

550.38 **1237**

Secular Magnetic Variations as Transients—W. M. Elsasser. (*Phys. Rev.*, vol. 68, p. 285; December 1–15, 1945.) The higher-harmonic components of the earth's magnetic field are subject to secular variations within periods of the order of a few hundred years. The inductance of the earth's metallic core is large, and periods of spontaneous decay of currents in the core are calculated to be of the order of 10^4 to 10^5 years. Abstract of an American Physiological Society paper.

551.594.223 **1238**

What Are Fireballs?—E. A. Logan. (*Elect. Rev.* (London), vol. 138, pp. 381–383; March 8, 1946.) It is suggested that fireballs (or ball lightning), which may be produced by cloud-to-cloud lightning, may be analogous to the vortex ring in structure.

LOCATION AND AIDS TO NAVIGATION

621.383 **1239**

Photoelectric Aid for the Blind—(*See* 1309.)

621.396.82: 621.396.9 **1240**

Radar Countermeasures—D. G. F. (*See* 1356.)

621.396[.9+.94 **1241**

A Note on the Detection of Undersea Craft by Means of Low Frequency Radiation from Aircraft—D. W. R. McKinley. (*Canad. Jour. Res.*, vol. 23, Sec. A, pp. 77–85; November, 1945.) "A semiquantitative examination is made of the chief factors affecting both the transmission of low-frequency radiation from an aircraft to a submarine and the return of this energy to the aircraft by scattering. A general expression is derived for the returning field strength, and graphs are shown for a representative set of conditions. It is indicated that, even under the most favorable conditions, the amount of energy returned is below the level of detectability, if the submarine is submerged more than 10 feet. However, it is also pointed out that communication between a shore station and an undersea craft should be feasible under certain conditions."

621.396.9 **1242**

Decca Navigator: Continuous-Wave Navigation System—(*Wireless World*, vol. 52, pp. 93–95; March, 1946.) Marine position finding by means of pulse transmissions is limited by the propagation characteristics of the very high frequencies implicit in the use of very short pulses. The Decca system uses continuous waves and can therefore take advantage of the more favorable ground-wave propagation characteristics of frequencies of the order of 100 kilocycles per second. For two synchronized transmitters, the loci of receiving points associated with given constant-phase differences are a family of hyperbolas. A third synchronized transmitter similarly determines another family of hyperbolas, and the ship can be located on the intersection of two hyperbolas by observations of the phase differences between the received signals. This is the essential theoretical basis of the Decca system. In practice, the master transmitter controls two remote phase-locked slave transmitters. The difficulty of distinguishing between three transmissions on the same frequency is overcome by using three different frequencies, each of which is a submultiple of the same higher frequency (e.g., 85 and 113.33 kilocycles per second, which are both submultiples of 340 kilocycles per second. The receiver receives each transmission separately and generates the appropriate harmonics for comparison of phase differences. This and other working details are described. See also 331 of February.

621.396.9 **1243**

Principles of Loran in Position Location—R. W. Kenyon. (*Elec. Ind.*, vol. 4, pp. 106–140; December, 1945.) See also 605 and 606 of March (D. G. F.).

621.396.9 **1244**

The Future of Radar—L. A. Du Bridge. (*Elec. Ind.*, vol. 4, pp. 77, 80; December, 1945.) Sea and air navigation will be greatly improved by the use of loran (long-range navigation) systems and by new microwave systems over shorter ranges. Summary of an Institute of Radio Engineers paper. See also *Electronics*, vol. 19, pp. 254–256; January, 1946.

621.396.9 **1245**

Fundamentals of Radar [:4]—(*Wireless World*, vol. 52, p. 65; February, 1946.) Correction to 927 of April.

621.396.9 **1246**

Radar in Merchant Ships—S. T. Allsop. (*Wireless World*, vol. 52, pp. 66–67; February, 1946.) General description of a compact set, easy to install and maintain, intended to give warnings of icebergs, other surface craft and, with its plan-position-indicator presentation, to show the position and outline of a coastline. The accuracy is about 2 degrees in bearing and 200 yards in range, with a maximum range of about 6 miles on a trawler target but considerably more for larger ships or for a coastline. Three plan-position-indicator displays are provided, one in the main chassis and two in remote positions convenient for navigation. Operating frequency evidently about 10,000 megacycles per second.

621.396.9 **1247**

Navigational Radar: Experimental Equipment for Use in Merchant Ships—(*Wireless World*, vol. 52, p. 89; March, 1946.) A description of a demonstration of a centimeter-wave plan-position-indicator system. "A demonstration run of nearly an hour's duration down one of the busiest shipping channels in the Thames Estuary showed that the ship could be conned with complete confidence through the traffic leaving ships and buoys a cable's length on either hand. During the whole time, the navigator based his helm orders solely on information given by the plan-position-indicator display."

621.396.9 **1248**

SCR-545 Radar—(*Electronics*, vol. 19, p. 198; January, 1946.) Correction to data given in 612 of March.

621.396.9 **1249**

Radar on 50 Centimeters—H. A. Zahl and J. W. Marchetti. (*Electronics*, vol. 19, pp. 98–104; January, 1946.) Description of the general arrangement, the aerial, and high-frequency system, of a light-weight 600-megacycle-per-second early warning radar type AN/TPS-3. Total weight, including generators and aerial, 1200 pounds. Range, 120 miles. The equipment can be erected by four men in half an hour. The transmitter uses a single VT158 pulsed at 200 cycles per second by a spark-gap modulator, and feeds an array of three dipoles with reflectors, mounted in the focal plane of a 10-foot-diameter paraboloid. The outer dipoles can be switched in or out of circuit to alter the coverage. The set gives range and azimuth only. Details are given of the rotating joint in the coaxial aerial feeder, and the transmit-receive system is illustrated. There is A-scope and plan-position-indicator display. To be continued.

621.396.9 **1250**

The [AN/] MPG-1 Radar—H. A. Straus, L. J. Rueger, C. A. Wert, S. J. Reisman, M. Taylor, R. J. Davis, and J. H. Taylor. (*Electronics*, vol. 19, pp. 110–117; January, 1946.) An account of the transmitting, radio-frequency receiver, and aerial systems of the 10,000-megacycle-per-second fire-control radar described in 610 of March. The modulator is of the hard-tube, capacitor-discharge type, with a pair of pulse transformers to enable the high-voltage pulse from the modulator to be taken by line to the magnetron. The stepup transformer has a double secondary connected to make the magnetron filament transformer remain at earth potential as the filament itself becomes highly negative. The radio-frequency system consists of a "squeeze box" standing-wave adjuster, transmit-receive, and anti transmit-receive switches, directional coupler monitor, rotating feed, horn, and reflector. The squeeze box enables the greatest magnetron frequency stability to be obtained. The radiator consists of a folded horn with a parabolic cylinder as reflector, and produces a beam about 0.6 degree wide and 3 degrees high. The scanning system is described.

621.396.9: 061.6 **1251**

History and Activities of the Radiation Laboratory of the Massachusetts Institute of Technology—L. A. DuBridge. (*Rev. Sci. Instr.*, vol. 17, pp. 1–5; January, 1946.) A wartime institution under the Office of Scientific Research and Development, set up to develop microwave radar.

621.396.9: 623.454.25 **1252**

Radio Proximity Fuze—Trotter. (*See* 1326.)

621.396.933.2 **1253**

Fundamentals of Radar: 5. Beacons Employing Pulse Technique—(*Wireless World*, vol. 52, pp. 55–56; February, 1946.) Radar beacons, developed from the identification-friend-or-foe system (3915 of 1945), with a transponder on the ground and an interrogator and responder in the aircraft, are used as homing and beam approach aids. With ranges up to 100 miles the aircraft may be within the working area of several beacons, so identification is given to each by interrupting the responses from the transponder. The equipment involved is simple, light, and cheap, and should be of great value in peacetime flying. See also 3914 of 1945.

621.396.933.2 **1254**

Direction Finder—M. Relson. (*Elec. Ind.*, vol. 5, pp. 120, 164; January, 1946.) "A Rotating radiation pattern is frequency modulated with a frequency identical [with], or an exact multiple of, the frequency of rotation of the beam. . . . Upon amplitude and frequency demodulation, two signals are obtained in the receiver, phase comparison of which indicates the position of the aircraft with respect to the transmitter station." Summary of U. S. Patent 2,377,902.

621.396.933.23 **1255**

Microwave Instrument Blind Landing System—Sperry Gyroscope Co. (*Elec. Ind.*, vol. 5, pp. 60–136; February, 1946.) Equipment operating at 2617 megacycles per second. Two transmitters in separate trailers and operating 23 megacycles per second apart feed parabolic reflectors to produce the glide and localizer paths. The beams are switched at 60 cycles per second to produce intersecting lobes which are modulated at 600 and 900 cycles per second, respectively. The receiver has a mechanical indicator to give the position of the plane relative to the correct approach line.

621.396: 629.13 **1256**

Aviation Radio [Book Review]—H. W. Roberts. W. Morrow and Co., New York, N. Y., 1945, 637 pp., $5.00. (*Elec. Ind.*, vol. 5, p. 162; February, 1946.) "A complete study of the subject usable both by the novice and the professional."

MATERIALS AND SUBSIDIARY TECHNIQUES

531.788 **1257**

Calibration of Ionization Gauge for Different Gases—S. Dushman and A. H. Young. (*Phys. Rev.*, vol. 68, p. 278; December 1–15, 1945.) Preliminary notice, including a table of results, of calibrations for He, Ne, A, Kr, Xe, Hg, H_2, N_2.

533.5 **1258**

A Metal Packless Vacuum Valve—E. Topanelian, Jr., and N. D. Coggeshall. (*Rev. Sci. Instr.*, vol. 17, p. 38; January, 1946.) An all-metal vacuum tube requiring no sealing grease or lubricant. A steel needle connected to a movable bellows engages a brass sealing. Pipe-line connections are through Kovar-to-glass seals.

534.845: 677.521 **1259**

A Discussion of the Acoustical Properties of Fiberglas—Rees and Taylor. (*See* 1156.)

537.228.1+539.32+621.3.011.5]: [546.32.85 +546.39.85 **1260**

The Elastic, Piezoelectric and Dielectric Constants of Potassium Dihydrogen Phosphate (KDP) and Ammonium Dihydrogen Phosphate (ADP)—W. P. Mason. (*Phys. Rev.*, vol. 68, p. 282; December 1–15, 1945.) Measurements have been made of all the elastic, piezoelectric, and dielectric constants of KDP and ADP crystals through temperature ranges down to the Curie temperatures. KDP behaves in accordance with theory, but ADP undergoes a transition at −125 degrees centigrade unconnected with the H_2PO_4 hydrogen bond system which controls the dielectric and piezoelectric properties. Abstract of an American Physical Society paper.

537.228.1+621.396.611.21 **1261**

The Acid Etching and Steam Treatment of Quartz Oscillator Plates—D. Fairweather. (*Marconi Rev.*, vol. 8, pp. 136–146; October/December, 1945.) The methods of finishing quartz oscillator plates to the desired frequency, for frequencies of 3 megacycles per second and higher, are examined critically. It is shown that for an etched plate $R=KF^2$, for constant etchant strength, where R is the rate of change of frequency, K is a constant, and F is the plate frequency. Steam treatment, with a similar law, has little value as a method of adjusting plates to frequency, but does provide an alternative method of aging and may be used to test the effectiveness of the etching processes.

537.228.1 **1262**

Methods of Orienting and Cutting Synthetic Crystals—W. L. Bond. (*Phys. Rev.*, vol. 68, p. 282; December 1–15, 1945.) The methods include optically orienting on a mounting board, securing by fast-setting cement, grinding a reference face at a predetermined angle from the board edges, sawing with solution-cooled abrasive blades, and grinding to dimension with abrasive belts. The application of these to ADP is discussed. Abstract of an American Physical Society paper.

537.228.1 **1263**

Apparatus for Growing Single Crystals from Solution—A. N. Holden. (*Phys. Rev.*, vol. 68, p. 283; December 1–15, 1945.) Abstract of an American Physical Society paper.

537.228.1 **1264**

The Order of Magnitude of Piezoelectric Effects—H. Jaffe. (*Phys. Rev.*, vol. 68, p. 282; December 1–15, 1945.) Piezoelectric coefficients are given as figures of merit for the selection of different materials for various applications. For sound generators, pickups, and microphones, Rochelle salt is still preferable, but for ultrasonic work in liquids, synthetic crystals may be preferred. Abstract of American Physical Society paper.

537.228.1: 537.531.9: 549.514.1 **1265**

Relation Between Darkening by X-Ray Irradiation and Permanence of Dauphiné Twinning in Quartz—E. Armstrong. (*Phys. Rev.*, vol. 68, p. 282; December 1–15, 1945.) Quartz plates were subjected to inversion to the high-temperature form and reinversion to low quartz. Each plate was then irradiated with X rays from a copper target tube. There was positive correlation between the amount of darkening caused by the X-ray irradiation and the permanence of their Dauphiné twin boundaries when subjected to the inversion treatment. Abstract of an American Physical Society paper.

621.315.52+621.315.559].018.44 **1266**

The Electrical Resistance of Iron Wires and Permalloy Strips at Radiofrequencies—A. W. Smith, J. H. Gregory, and J. T. Lynn. (*Jour. Appl. Phys.*, vol. 17, pp. 33–36; January, 1946.) Substitution of test specimens of the materials in place of a series of standard resistors in a circuit resonant at the required radio frequency f (between 1.5 and 6 megacycles per second) enables the alternating-current resistance R of the specimens to be obtained by interpolation. Comparison with the direct-current resistance R_0 gives an empirical equation $R/R_0=0.4+1.5d(f\mu o/10^3)^{1/2}$ for iron wire and $R/R_0=A+f(a/b)1.12(fabo\mu/10^3)^{1/2}$ for permalloy strip of dimensions $a\times b$. d = wire diameter (centimeters), f = frequency (megacycles per seconds), μ = permeability (gauss/oersted), o = conductivity (mhos per centimeter), A = empirical constant for each specimen, $f(a/b)$ = a function obtained from Cockroft (1929 abstracts, page 224). These results are compared with existing theoretical work. "The relatively simple form of the empirical equation supports the hope that a definite physical meaning can be assigned to · · · A and · · · $f(a/b)$.

621.315.61 **1267**

Radio Insulating Materials: Part 4—A. H. Postle. (*Radio*, vol. 29, pp. 33–60; December, 1945.) Preparation and properties of compression-moulded and transfer-moulded glass-bonded mica (permittivity 7). Higher permittivity materials (ϵ up to 20) in moulded forms, and temperature compensating materials having permittivities up to 80 and a temperature capacitance coefficient of 1 in 10^3 are available. For part 3, see 632 of March.

621.315.613.1 **1268**

Electrical Properties of Indian Mica: II. The Effect of Varying Relative Humidity—P. C. Mahanti, M. K. Mukherjee, and P. B. Roy. (*Indian Jour. Phys.*, vol. 19, pp. 83–92; June, 1945.) A continuation of the work described in 3543 of 1943 (Datta, Gupta, and Mahanti). The measurement was by substitution by a standard air capacitor in a Schering bridge. Various methods of maintaining a known humidity in an enclosed space are described, including the use of saturated aqueous solutions of a range of salts such as calcium chloride, calcium sulphate, etc. The method chosen was the use of aqueous solutions of glycerin. This has the important advantage that the relative vapor pressure is substantially independent of temperature over the range 0 to 70 degrees centigrade, and that the solutions are easily standardized by measurement of refractive index. The results confirm those obtained by previous workers. The power factor begins to rise at about 40 per cent relative humidity and rises steeply beyond 80 per cent.

621.315.614: 621.315.615 **1269**

The Electrical Resistivity of Resin-Treated Wood and Laminated Hydrolyzed-Wood and Paper-Base Plastics—R. C. Weatherwax and A. J. Stamm. (*Trans. A.I.E.E.* (*Elec. Eng.*, December, 1945), vol. 64, pp. 833–838; December, 1945.) A report on measurements giving experimental details. Graphs and data supplied show the variation of surface and volume resistivity with moisture content, resin content, and relative humidity for the types of wood examined.

621.318[.22+.322 **1270**

Magnetic Materials—F. E. Robinson. (*Marconi Rev.*, vol. 8, pp. 125–135; October/December, 1945.) A review of recent improvements in the properties of hard and soft magnetic materials, obtained by cold working, heat treatment, and variations of composition. The materials considered are divided into three groups, those suitable for permanent magnets, for power apparatus such as low-frequency generators, motors and transformers, and for sound and radio apparatus at frequencies, up to 1 megacycle per second.

621.318.322.017.3 **1271**

Hysteresis and Eddy Losses in Single Crystals of an Alloy of Iron and Silicon—A. J. C. Wilson. (*Proc. Phys. Soc.*, vol. 58, pp. 21–29; January 1, 1946.) The total energy dissipated in single crystals of iron containing 2.1 per cent silicon has been measured calorimetrically, for fields in the three crystallographic directions [100], [110], and [111], the losses being analyzed by variation with frequency. The eddy losses do not depend on field direction, but the hysteresis loss for [100] is about one-third that for the other directions. A tentative theory is put forward.

621.385.832 1272

Phosphors and Their Behavior in Television Part I—I. Krushel. (*Elec. Ind.*, vol. 4, pp. 100–134; December, 1945.) A general account of the properties of phosphors, including graphs showing spectral properties of common types, with a description of manufacturing processes.

621.385.832 1273

Phosphors and Their Behavior in Television Part II—I. Krushel. (*Elec. Ind.*, vol. 5, pp. 92–150; January, 1946.) The following production methods of coating tubes are described and their advantages discussed: spraying, dusting, settling, "flowing-on," and electrostatic deposition. Problems of "ion burn" and dissipation of screen charges are specifically treated. Contrast and brilliancy, although sufficient for direct viewing, are not at present adequate for satisfactory projection. For part I, see 1272.

621.315.6(083.75) 1274

ASTM Standards on Electrical Insulating Materials (with related information) [Book Review]—ASTM Committee D-9. American Society for Testing Materials, Philadelphia, Pa., 1945, 560 pp., $3.25. (*Elec. Eng.*, vol. 65, pp. 97–98; February, 1946.)

621.357.7 1275

Electroplating, A Survey of Modern Practice, including the Analysis of Solutions [Book Review]— S. Field and A. D. Weill. Pitman Publishing Corp., New York, N. Y. fifth edition, 1945, 483 pp., $5.00. (*Elec. Eng.*, vol. 64, p. 470; December, 1945.)

MATHEMATICS

517.432 1276

The Steady-State Operational Calculus—D. L. Waidelich. (Proc. I.R.E. and Waves and Electrons, vol. 34, pp. 78P–83P; February, 1946.) "The direct and inverse transforms of the steady-state operational calculus are presented, together with two methods of evaluating the inverse transform, the first resulting in a Fourier series and the second giving a sum function. A proof of the inversion theorem connecting the two transforms is outlined in the Appendix. Two examples are presented illustrating the application of this operational calculus to circuit problems, and a comparison is made between the ordinary and the steady-state operational calculuses."

517.941.91 1277

Computation of the Solution of Mathieu's Equation—N. W. McLachlan. (*Phil. Mag.*, vol. 36, pp. 403–414; June, 1945.)

517.5(021) 1278

Lehrbuch der Funktionentheorie—Vols. I and II [Book Review]—L. Bieberbach. Chelsea Publishing Co., New York, N. Y., 1945, Vol. I (fourth edition, 1934) 320 pp., $3.50, Vol. II (second edition, 1931) 368 pp., $3.25. (Proc. I.R.E. and Waves and Electrons, vol. 1, p. 104 W, February, 1946.) American reprint of the German text.

517.564.4: 518.2 1279

Tables of Associated Legendre Functions [Book Review]—Mathematical Tables Project. Columbia University Press, New York, N. Y., 1945, 303 pp., $5.00. (*Electronics*, vol. 19, p. 344; January, 1946.) Fourteen major tables of functions and their first derivatives with five supplementary tables. To about six significant figures at intervals of 0.1.

621.396.029.6 1280

The Mathematics of Ultra-High Frequencies in Radio [Book Review]—L. N. Brillouin. Brown University, Providence, R. I., 1943, 210 pp. (*Proc. Phys. Soc.*, vol. 58, pp. 128–129; January 1, 1946.) A mimeographed record of a course of lectures at Brown University.

MEASUREMENTS AND TEST GEAR

621.3.012.3: 621.3.081.4 1281

Decibel Conversion Chart—R. C. Miedke. (Proc. I.R.E. and Waves and Electrons, vol. 1, pp. 76W–77W; February, 1946.) The chart gives decibels directly from any two values of voltage, current, or power, for ratios up to 10 to 1, with an extended range for ratios up to 10^6 to 1.

621.317.32: 537.221 1282

A Modified Kelvin Method for Measuring Contact Potential Differences—W. E. Meyerhof and P. H. Miller, Jr. (*Rev. Sci. Instr.*, vol. 17, pp. 15–17; January, 1946.) The two surfaces are brought rapidly together and give a pulse to an electrometer tube used as a cathode follower. By adjusting the bias, this pulse is reduced to zero and measures the contact potential difference to 0.01 volt.

621.317.32.015.33: 621.385.2 1283

Pulse Response of Diode Voltmeters—A. Easton. (*Electronics*, vol. 19, pp. 146–149; January, 1946.) A theoretical and experimental investigation. Equation (11) gives the mean rectified voltage in terms of the parameters of the pulse and the voltmeter, and is closely confirmed by experiment. It is stressed that the input impedance may be relatively small for short pulses. When measuring very short pulses, the voltmeter performance can be improved by the use of a cathode follower and a pulse-stretching circuit; a practical arrangement is shown.

621.317.382.029.3 1284

Power Measurements at Audio Frequencies—D. L. Waidelich. (*Elec. Ind.*, vol. 5, pp. 68–70; February, 1946.) Describes the three-voltmeter method as given by Laws in his book "Electrical Measurements" (2508 of 1938). A second method, using a network and two thermojunction milliammeters with the output electromotive forces connected in opposition, has a linear calibration. Variable resistors are used for setting up the scale accurately. The relative advantages of the two systems are enumerated.

621.317.39 1285

Electric Measuring Instruments—D. M. Nielsen. (*Elec. Eng.*, vol. 65, pp. 66–74; February, 1946.) A survey of the instruments used for the measurement of process variables such as temperature, pressure, flow, pH, etc., in terms of electrical variables, and of the way in which electronic devices are influencing the design of the sensitive elements, measuring mechanisms, and controlling mechanisms of the instruments. Table I lists electrically sensitive elements in terms of the physical variable measured, and Table II gives additional applications where the electrical element is combined with another responsive element. The basic features of electronic measuring instruments in general are given together with detailed descriptions of a commercial self-balancing bridge and three self-balancing potentiometers. Reasons are given for the increased use of electronic and electromechanical devices.

621.317.41+621.317.43]:621.318.323.2.029.5 1286

Proposed Test Coils—(*Elec. Ind.*, vol. 5, p. 71; January, 1946.) "Tentative standards for testing permeability and Q of powdered iron slugs $\frac{3}{8}$ inch in diameter and $\frac{3}{4}$ inch long."

621.317.42 1287

Fluxmeter—Marion Electric Instrument Co. (*Rev. Sci. Instr.*, vol. 17, p. 41; January, 1946.) A direct-reading fluxmeter with overall accuracy better than 1 per cent. A D'Arsonval movement is situated in the field to be measured and the current observed that is required to give a standard deflexion. Field range 1200 to 9600 gauss.

621.317.7+621.38+621.396.69 1288

Physical Society's Exhibition: First Post-war Show of Testing and Measuring Gear—(*Wireless World*, vol. 52, pp. 48–52; February, 1946.) See also 1131/1133 of April.

621.317.7 1289

The Physical Society's Thirtieth Annual Exhibition: Electrical Instruments—G. H. Rayner. (*Jour. Sci. Instr.*, vol. 23, pp. 31–34; February, 1946.) A review of instruments including the electron microscope, voltmeters, frequency meters, alternating-current bridges, oscillators, signal generators, and a new alternating-current—direct-current comparator. See also 1131/1133 of April.

621.317.71: 621.396.67 1290

Remote Indicating Antenna Ammeter—C. R. Cox. (*Electronics*, vol. 19, pp. 210–214; January, 1946.) A diode rectifier coupled to the antenna through a current transformer, with a direct-current microammeter giving approximately linear calibration.

621.317.734 1291

A Simple Ohmmeter—"Calibrator." (*Wireless World*, vol. 52, p. 44; February, 1946.) Brief description of a circuit in which a single milliammeter is used alternately for measuring the current through and the potential drop across the unknown resistor. Resistances up to 10^5 ohms can be measured.

621.317.734 1292

Resistance Measurements—S. Litt. (*Radio News*, vol. 35, pp. 44–135; January, 1946.) Review of various methods of resistance measurement, including commercial ohmmeters with accuracy of 1 per cent for very low resistance values, and bridge-type ohmmeters of greater accuracy.

621.317.76: 621.396.621 **1293**

Laboratory Receiver—W. F. Frankart. (*Elec. Ind.*, vol. 5, pp. 71, 144; February, 1946.) Circuit details of a high-stability very-high-frequency receiver for frequency deviation and mean carrier-frequency measurements. It includes a radio-frequency stage, a frequency changer, and separate intermediate-frequency channels for amplitude and frequency modulation.

621.317.761+621.396.611.21.029.3 **1294**

Stabilizing Frequency in LF [1–10 kc/s] Crystal Oscillators—L. R. Cox. (*Elec. Ind.*, vol. 5, pp. 106–124; February, 1946.) The amplitude-frequency effect in duplex flexure mode is reduced from 2 in 10^5 to a few parts in 10^7 by the use of a varistor in a voltage-limiting circuit. Summary of U. S. Patent 2,385,260.

621.317.761.029.62/.64 **1295**

Introduction to U. H. F. Frequency Measurements—G. Dexter. (*Radio News*, vol. 35, pp. 32–114; January, 1946.) The principles and limitations of various methods of frequency measurement above 150 megacycles per second are described, including inductance-capacitance wavemeters and Lecher-wire systems. A cavity resonator with crystal detector, and a heterodyne instrument with butterfly oscillator and crystal mixer, are described rather more fully.

621.317.79: 537.228.1 **1296**

Quartz Crystal Measurement—C. W. Harrison. (*Radio*, vol. 29, pp. 16–22; December, 1945.) Illustrated summary of 3325 of 1945.

621.317.79: 621.396.615.12 **1297**

Test Oscillator for New AM-FM-Tele Needs—W. Muller. (*Elec. Ind.*, vol. 5, pp. 86–89; February, 1946.) The necessary and desirable properties of a versatile standard-signal generator for frequency modulation and television frequencies are considered, and the design of a suitable instrument is discussed in detail. It covers the ranges 100 kilocycles per second to 150 megacycles per second, and 1 microvolt to 1 volt, with provision for frequency modulation and amplitude modulation, and incorporates crystal-controlled oscillators at 100 kilocycles per second and 1 megacycle per second. It is claimed to be "almost foolproof and obsolescence-proof."

621.317.79: 621.396.615.14 **1298**

135 to 500 Megacycle Signal Generator—J. Wonsowicz and H. S. Brier. (*Radio News*, vol. 35, pp. 35–116; January, 1946.) A design within the scope of a home workshop is described. The frequency range of nearly 4 to 1 on an single band is given by a tank circuit of novel construction. An unbalanced output is obtained through a simple coaxial tapped-line attenuator. Modulation at 400 and 1000 cycles per second is provided.

621.317.79: 621.396.62 **1299**

R.F.-I.F.-A.F. Signal Tracer for Receiver Testing—V. Cavaleri. (*Radio News*, vol. 35, pp. 50–133; January, 1946.) A 3-tube audio-frequency amplifier of which the input circuit acts as grid-leak detector for modulated radio-frequency and intermediate-frequency signals. A magic-eye indicator is used for continuous-wave signals. Constructional details.

621.392.43 **1300**

Shunt and Series Sections of Transmission Line for Impedance Matching—Tai. (*See* 1178.)

621.315.6(083.75) **1301**

ASTM Standards on Electrical Insulating Materials (with related information) [Book Review]—ASTM Committee D-9. (*See* 1274.)

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

534.321.9: 620.179 **1302**

Supersonic Flaw Detector—(*See* 1148/1149.)

537.531 **1303**

Some Experiences with the X Ray—W. D. Coolidge. (*Elec. Eng.*, vol. 64, pp. 423–426; December, 1945.) Personal reminiscences of the author's work in the early days of X-ray development. Voltage-supply difficulties are mentioned and also modifications to tubes for practical application of X rays. The article also appears in *Amer. Jour. Roentgenol.*

537.531: [5+6 **1304**

Scientific Importance of X-Rays—L. H. Garland. (*Elec. Eng.*, vol. 64, pp. 437–444; December, 1945.) An outline of the applications and value of X rays to industry and science in general, and particularly to medical science.

537.531: 62 **1305**

Industrial X-Ray Developments—C. D. Moriarty. (*Elec. Eng.*, vol. 64, pp. 433–435; December, 1945.) An account giving special attention to modern methods of recording results. Radiographic, fluoroscopic, and electrical methods of recording are discussed.

612.82.014.421: 621.395.645 **1306**

Brain Wave Records in Medical Diagnosis—F. Offner. (*Elec. Ind.*, vol. 5, pp. 72–161; January, 1946.) The recording of potential differences on the surface of the scalp needs amplifiers with a frequency response from a fraction of a cycle to 10 kilocycles per second, and an amplification of about 140 decibels. Four- or five-stage resistance-capacitance-coupled push-pull amplifiers with balanced input are used. A Rochelle-salt—crystal-driven recorder gives a satisfactory recording speed for use up to 100 cycles per second.

621.365[.5+.92 **1307**

Case Studies of RF Heating—Westinghouse Electric Corporation. (*Elec. Ind.*, vol. 5, pp. 84–85; January, 1946.) Eight annotated photographs showing methods of solving typical industrial problems.

621.365.92: 615.452 penicillin **1308**

Radio-Frequency Dehydration of Penicillin Solution—G. H. Brown, R. A. Bierwirth, and C. N. Hoyler. (PROC. I.R.E. AND WAVES AND ELECTRONS, vol. 1, pp. 58–65; February, 1946.) Preliminary concentration of the solution under reduced pressure is effected by using a 2-kilowatt, 28-megacycle-per-second oscillator. Further dehydration in bottles revolving at high speed reduces the moisture content to 4 per cent in 3 minutes. The equipment can produce 2000 dry bottles each hour.

621.383 **1309**

Photoelectric Aid for the Blind—(*Electronics*, vol. 19, pp. 204–210; January, 1946.) A device which is used to scan the path ahead. A beam of light is projected, and any reflection from objects is detected by a photocell which produces coded tone signals in an earphone. The range limit is 20 feet, and the coded signal heard indicates the distance of the object. The equipment weighs 9 pounds, but may be reduced to about 2 pounds.

621.383: 535.33.071 **1310**

Electronic Spectroscopy—G. C. Sziklai and A. C. Schroeder. (*Phys. Rev.*, vol. 68, p. 284; December 1–15, 1945.) The color content of light falling on a photocell may be directly observed on an oscilloscope. The method lends itself to color-matching by using two similar devices giving signals of opposite polarity and hence zero combined output when the colors match. Abstract of an American Physical Society paper.

621.384 **1311**

Production of Particle Energies Beyond 200 Mev—L. I. Schiff. (*Rev. Sci. Inst.*, vol. 17, pp. 6–14; January, 1946.) The betatron, synchrotron, microtron, linear resonator accelerator, linear wave-guide accelerator, and relativistic ion cyclotron are proposed and briefly described.

621.385 **1312**

Physical Limitations in Electron Ballistics—Pierce. (*See* 1395.)

621.385.833 **1313**

Space Charge-Limited Beams in Electrostatic Fields—M. E. Rose. (*Phys. Rev.*, vol. 68, p. 287; December 1–15, 1945.) The case dealt with is the circularly symmetric beam of finite cross section. Only first-order optics in which the aberration is due to space charge is treated. Abstract of an American Physical Society paper.

621.385.833 **1314**

On the Improvement of Resolution in Electron Diffraction Cameras—J. Hillier and R. F. Baker. (*Jour. Appl. Phys.*, vol. 17, pp. 12–22; January, 1946.)

621.385.833 **1315**

Complete Computation of Electron Optical Systems—H. Motz and L. Klanfer. (*Proc. Phys. Soc.*, vol. 58, pp. 30–41; January 1, 1946.) The field of the system is calculated by relaxation (see also 658 of March—Motz and Worthy), and the electron trajectories by step-by-step integration. "The position of focal and cardinal points and the spherical aberration of the lens are found to be in fair agreement with experimental and semi-empirical determinations by other authors."

621.385.833 **1316**

Applied Electron Microscopy—J. H. L. Watson. (*Canad. Jour. Res.*, vol. 21, Sec. A, pp. 89–98; November, 1943.) The technique of taking stereoscopic photographs, and its adaptation to give electron diffraction patterns, is described in relation to the examination of mine dust, clays, and the structure of botanical specimens.

621.385.833 **1317**

Electron Miscroscope Society of America

—(*Jour. Appl. Phys.*, vol. 17, pp. 66–68; January, 1946.) Abstracts of 25 papers from the Society's program.

621.385.833 1318
Applications of Metallic Shadow-Casting to Microscopy—R. C. Williams and R. W. G. Wyckoff. (*Jour. Appl. Phys.*, vol. 17, pp. 23–33; January, 1946.)

621.385.833 1319
A High Speed Microtome for the Electron Microscope—E. F. Fullam and A. E. Gessler. (*Rev. Sci. Instr.*, vol. 17, pp. 23–35; January, 1946.)

621.389: 778.52 1320
Electronic Timing of Sequence Photographs—C. H. Coles. (*Elec. Ind.*, vol. 5, pp. 74–76; February, 1946.) Circuit details and photographs of apparatus for photographing bullets in flight. A rising voltage is applied to a number of tubes biased to different amounts beyond cutoff. As each tube conducts, it applies a pulse to a stroboscopic lamp. Six lamps may be fired in succession in a time between 35 microseconds and $\frac{1}{2}$ second.

621.398: 621.318.5 1321
Industrial Relay Control Circuits—R. R. Batcher. (*Elec. Ind.*, vol. 5, pp. 94–134; February, 1946.) Methods of remote control are outlined. The operation of simple relays is described, and it is shown how complex problems are solved by combinations of relays. Selective control is effected by pulse-operated switching circuits of the types used in telephone exchanges.

621.398: 623 1322
Radio Control of German V-2 Rockets—(*Elec. Ind.*, vol. 4, p. 89; December, 1945.) Brief note only. See also 4135 of 1945.

621.398: 629.13 1323
Radio Operated Airplane—S. R. Winters. (*Radio News*, vol. 35, pp. 29–159; January, 1946.) Four audio-frequency tones on an ultra-high-frequency carrier control a small plane. Switching off a fifth tone stops the engine and releases a parachute. See also 1324 below.

621.398: 629.13 1324
Radio-Controlled Target Airplane Developed by ATSC—(*Radio News*, vol. 35, p. 66; January, 1946.) See also 1323 above and 1013 of April.

623.26: 621.396.9 1325
Vehicular-Mounted Mine Detector—H. G. Doll, M. Lebourg, and G. K. Miller. (*Electronics*, vol. 19, pp. 105–109; January, 1946.) A device that automatically stops the vehicle on detection of a metal mine or on failure of the electronic apparatus. Four circular horizontal coils side by side and in series are transmitters (presumably alternating frequency). Four receiving coils are fixed on top of the transmitters, and the mutual inductance between transmitting and receiving circuits is neutralized by a group of transformers in opposite polarity in series with the coils. The coil assembly forms the detector element, and is electrostatically screened. Residual signal in the receiving circuit is neutralized by the injection of a signal automatically controlled by a long-time-constant circuit to counteract drift from balance. Passage of the detector over a mine causes a sudden change in mutual impedance between the coils, too quick for automatic compensation, and the resulting signal in the receiver operates braking relays. The arrangement is particularly sensitive to change in the resistive component of the mutual impedance, which is of advantage in discriminating against false signals. The complete circuit diagram is given with component values.

623.454.25: 621.396.9 1326
Radio Proximity Fuze—H. Trotter, Jr. (*Electronics*, vol. 19, pp. 226–228; January, 1946.) Summary of an Institute of Radio Engineers paper describing the history of the subject.

016: 621.386.1: 620.179 "1942/1945" 1327
Bibliography on Industrial Radiology [Book Review]—H. R. Isenburger. St. John X-Ray Service, Inc., Long Island City, N. Y., 16 pp., $1.00. (*Electronics*, vol. 19, p. 344; January, 1946.) Mimeographed list of about 400 items published between 1942 and 1945. Supplement to 723 of 1944.

621.38: 62 1328
Elementary Engineering Electronics [Book Review]—A. W. Kramer. Instruments Publishing Co., Pittsburgh, Pa., 1945, 344 pp., $2.00. (*Elec. Ind.*, vol. 5, p. 128; January, 1946.)

PROPAGATION OF WAVES

534+538.56 1329
The Wave Equation in a Medium with a [space] Variable Index of Refraction—P. G. Bergmann. (*Phys. Rev.*, vol. 68, p. 286; December 1–15, 1945.) Abstract of an American Physical Society paper.

621.396.11 1330
Polarized Radiation—J. Grosskopf and K. Vogt. (*Elec. Ind.*, vol. 4, p. 113; December, 1945.) Summary of 2842 of 1944, with two graphs.

621.396.11 1331
Propagation Effects—(*Elec. Ind.*, vol. 5, pp. 65–142; February, 1946.) A brief report of a conference held at the Cosmic Terrestrial Research Laboratory, Needham, Mass., on December 11, 1945, on ionospheric and tropospheric propagation. Ionospheric and path absorption, sporadic "E," and scatter were discussed. Extended fadeouts were reported on 110 megacycles per second over a distance of 70 miles which were greatly reduced by operation in the 40- to 50-megacycle-per-second band. See also 1334.

621.396.11: 523.746.5: 551.15.053.5 1332
The New Sunspot Cycle—Bennington. (*See* 1235.)

621.396.11: 621.396.812.3 1333
Irregularities in Radio Transmission: Part 1—O. P. Ferrell. (*Radio*, vol. 29, pp. 27–61; December, 1945.) A review of evidence that "bursts" are due to low-level ionospheric reflections. A graph representing measurements made over 337- and 720-mile paths at a frequency of 42.3 megacycles per second shows the average number of bursts per hour against field intensity of the received signal. The curve falls from 80 bursts per hour exceeding 6 microvolts per meter to 2 bursts per hour exceeding 26 microvolts per meter. Twenty references are given.

621.396.11.029.62 1334
Tropospheric Study of FM Transmission—C. W. Carnahan. (*Elec. Ind.*, vol. 4, pp. 78–146; December, 1945.) A long account of the Institute of Radio Engineers paper by Carnahan. See also 1028 of April, and 1335 below.

621.396.11.029.62 1335
FM Tests—F. C. C. (*Elec. Ind.*, vol. 4, pp. 80–81; December, 1945.) Report of controversy over the significance of results given in 1028 of April and in 1334 above (Carnahan). Federal Communications Commission tests at 20 miles range are stated to indicate the reverse of the conclusions drawn from Carnahan's measurements.

621.396.11.029.64+538.569.4 1336
The Absorption of Microwaves by Gases—W. D. Hershberger. (*Phys. Rev.*, vol. 68, p. 284; December 1–15, 1945.) Fourteen gases give absorptions at about 1 centimeter wavelength comparable with that of ammonia. The frequency at which the absorption coefficient is maximum is obtained from graphs of the coefficient against pressure. Abstract of an American Physical Society paper.

621.396.615.17 1337
A New Pulse Generator Circuit [useful for ionospheric sounding]—Banerjee. (*See* 1210.)

RECEPTION

621.394/.397].813 1338
Defining Distortion—M. G. Scroggie. (*Wireless World*, vol. 52, pp. 99–100; March, 1946.) A letter criticizing the following definitions in the British Standard Glossary of Terms used in Telecommunication: 1301 Distortion; 1302 Attenuation Distortion; 1304 Delay Distortion; 1305 Nonlinear Distortion, 1307 Harmonic Distortion; 1308 Intermodulation Distortion.

621.396.61/.62+621.395.645 1339
Low Power Transmitting, Receiving, and Hailing Equipment. Type CNY. 1—Morcom. (*See* 1386.)

621.396.62: 621.396.662 1340
A Simple Remote Tuning Device for Receivers—E. L. Hannum, Jr. (*Radio News*, vol. 35, pp. 76, 82; January, 1946.) Bandspread about a selected communication frequency is achieved by varying the grid bias of a reactor vacuum tube connected across the tuned circuit of the receiver local oscillator, using a direct-current line circuit with remote potential-divider control. The control line is also used to carry the receiver audio-frequency output to the control point. The system is useful when it is necessary to locate a receiver perhaps several miles from the control center in order to avoid noise interference with reception.

621.396.621: 621.317.76 1341
Laboratory Receiver—Frankart. (*See* 1293.)

621.396.621.54 1342
Practical Radio Course: Part 40—A. A. Ghirardi. (*Radio News*, vol. 35, pp. 57–151; January, 1946.) "The effects [and causes

of resonant-frequency 'drifts' in the preselector, intermediate-frequency amplifier, and oscillator-tuning circuits of a superheterodyne-type receiver."

621.396.621.54 1343
Amateur Communication Receiver—H. B. Dent. (*Wireless World*, vol. 52, pp. 36–40; February, 1946.) The basis of the design of a short-wave superheterodyne receiver with two frequency conversions. The conversion is first to 1.8 megacycles per second and second to 100 kilocycles per second, giving good second-channel and adjacent-channel selectivity. The circuit diagram is given.

621.396.621.59 1344
Discriminating between Signals of Different Amplitude—E. H. Ullrich. (*Elec. Ind.*, vol. 4, pp. 120, 170; December, 1945.) "A method which permits the separation of pulse-modulated waves where the frequency and the energy at the receiver may be identical, but the amplitude and/or duration are different." Summary of U. S. Patent 2,381,847.

621.396.621.59 1345
Exalted-Carrier Amplitude- and Phase-Modulation Reception—M. G. Crosby. (PROC. I.R.E. AND WAVES AND ELECTRONS, vol. 34, p. 90P, February, 1946.) Discussions of 3516 of 1945.

621.397.8 1346
Television for Urbanized Areas [siting of aerials]—Duvall. (*See* 1384.)

STATIONS AND COMMUNICATIONS SYSTEMS

621.396.619 1347
Phase and Frequency Modulation—E. Green (*Marconi Rev.*, vol. 8, pp. 113–118; October/December, 1945.) Vector diagrams are used to show the relationship between phase and frequency modulation, and to derive the relative gain in signal-to-noise ratio of these types of modulation over amplitude modulation for various values of modulation index.

621.396.619: 621.385.5 1348
Phasitron Converts from AM to FM Directly—(*See* 1405.)

621.396.619.018.41 1349
Frequency Modulator—D. A. Bell. (*Elec. Ind.*, vol. 5, pp. 118, 120; January, 1946.) When two signals at different frequencies are applied to a limiter, one component of the output has a frequency intermediate between the input frequencies, dependent on the relative amplitude of the inputs. Thus if one input is amplitude-modulated, this output component is correspondingly frequency-modulated. Summary of U.S. Patent 2,384,789.

621.396.619.16 1350
Pulse Position Modulation Technic—(*Elec. Ind.*, vol. 4, pp. 82–190; December, 1945.) A detailed general technical account of the Bell system described in 740 of March, including block diagrams and some circuit diagrams of the equipment.

621.396.619.16 1351
Pulse Modulation—F. F. Roberts and J. C. Simmonds. (*Wireless Eng.*, vol. 23, p. 93; March, 1946.) Suggested definitions and abbreviations for terms used in the various forms of pulse modulation. Sharp leading and trailing edges are assumed. See also 1053 of April (Cooke) and 183 of January (Roberts and Simmonds).

621.396.619.16 1352
Pulse-Time Modulation: An Explanation of the Principle—(*Wireless World*, vol. 52, pp. 45–46; February, 1946.)

621.396.65.029.62/.64 1353
The [U.S.] Army's Radio Relay Equipment—A. R. Boone. (*Radio News*, vol. 35, pp. 25–155; January, 1946.) The AN/TRC-1 is a frequency-modulation set transmitting at 70 to 100 megacycles per second from a double-H aerial, providing four telephone channels. The AN/TRC-8 is similar but operates at 230 to 250 megacycles per second, using a dipole with a V reflector. The AN/TRC-6 (4300 to 4900 megacycles per second) uses eight interlaced pulse-position-modulated channels. The aerial is a parabolic reflector with waveguide feed. The AN/ATRC-5 is similar, but uses a dipole with paraboloid reflector (1350–1450 megacycles per second). Advantages over wire circuits include reduction in installation time, and in the number of repeater stations needed. For descriptions of AN/TRC-5 and AN/TRC-6, see 1055/1056 of April and back references.

621.396.7 1354
The [U.S.] Signal Corps on and in the Air—C. E. Jackson. (*Radio News*, vol. 35, pp. 94–98; January, 1946.) A complete airborne radio station to meet the speed, mobility, and power required in Pacific operations was prepared, using three cargo planes. The 3-kilowatt transmitter and 15-kilowatt diesel generator were carried in separate planes, parked nose to nose, with a 38-foot horizontal aerial using the aircraft as counterpoise. The receiver plane, some half-mile away, was linked by land line. A two-tone teletype system was used.

621.396.712 1355
FM in Canada—D. Holloway. (*Radio News*, vol. 35, pp. 30–140; January, 1946.) An account of controversial problems of broadcast policy.

621.396.82: 621.396.9 1356
Radar Countermeasures—D.G.F. (*Electronics*, vol. 19, pp. 92–97; January, 1946.) Description of methods of searching for, locating, and jamming enemy radars. Wide-range automatically tuned receivers with tape recording and an oscillographic analyzer are used for searching. Jamming is provided by tunable high-power transmitters having random-noise modulation, or by reflecting foil strips of suitable length ("window" or "chaff"). Wide-band aerial systems and the resnatron (a tetrode giving 30 kilowatts continuous wave at 500 megacycles per second) are briefly described. The more commonly used equipment is described in tabular form. See also 1059/1061 of April.

621.396.931.029.62 1357
Multi-Carrier Communication System: Diversity Transmission for Mobile Working—(*Wireless World*, vol. 52, pp. 59–61; February, 1946.) General description of a system used by the London police and fire services. Reliable two-way telephone communication with mobile units can be maintained over a service range of 20 miles using amplitude modulation, and frequencies near 100 megacycles per second, with a 400- to 500-foot mast at the control center. The service area is extended by using additional fixed stations, supplied with synchronized and correctly phased modulation, operating at frequencies sufficiently close to one another to be within the bandwidth of the receivers, but sufficiently far apart to avoid audible beats. Signals from the mobile transmitters can be received at any of the fixed stations and relayed to the control center. The system is described in detail in an Institution of Electrical Engineers paper by J. R. Brinkley, not yet printed.

621.396.931.029.63 1358
2660-Mc Train Communication System—E. A. Dahl. (*Electronics*, vol. 19, pp. 118–122; January, 1946.) A description of a two-way frequency-modulation system, for communication between front and rear of train, and from train to wayside stations. The equipment consists of two compact units, transceiver, and power supplies. The 10-watt transmitter uses a crystal-controlled oscillator, its frequency multiplied up to 2660 megacycles per second in five stages, the last by a klystron. The signal is then klystron-amplified and fed to the aerial. For reception, the same frequency-multiplying chain is used with a crystal of slightly different frequency to serve as local oscillator, which, mixed with the incoming signal, gives an intermediate frequency of 7 megacycles per second. The omniazimuthal antenna consists of six vertically stacked units, each having three curved dipoles, arranged in a circle at the focus of a biconical parabolic reflector.

621.396.97: 356.251.11. 1359
Listening to the World—C. Cross. (*Radio News*, vol. 35, pp. 64–141; January, 1946.) A nontechnical review of the British Broadcasting Corporation's wartime monitoring service. See also 197 of January.

621.396: 629.13 1360
Aviation Radio [Book Review]—Roberts. (*See* 1256.)

SUBSIDIARY APPARATUS

539.16.08 1361
Experiments with Triode [particle-] Counters—S. A. Korff. (*Phys. Rev.*, vol. 68, p. 284; December 1–15, 1945.) Abstract of an American Physical Society paper.

621–526 1362
Electrical Analogy Methods Applied to Servomechanism Problems—G. D. McCann, S. W. Herwald, and H. S. Kirschbaum. (*Trans. A.I.E.E.* (*Elec. Eng.*, February, 1946), vol. 65, pp. 91–96; February, 1946.) The treatment of angular-position mechanisms and a description of the transient analyzer are given, with typical transient-response curves. Effects of varying controlling parameters are shown.

621.314.634: 621.396 1363
Dry-Contact Rectifiers for Radio Applications—G. Herbert. (*Radio*, vol. 29, pp. 29–61; December, 1945.) Details of construction and performance of selenium rectifiers, including efficiency, regulation, and current

characteristics. A chart shows sizes and current capacity of rectifier plates.

621.314.67 1364
Capacitor-Charging Rectifier—H. J. Bichsel. (*Electronics*, vol. 19, pp. 123–125; January, 1946.) Experimental determination of design criterion for a reactance-limited rectifier required to charge a large capacitor bank in the shortest time and with the least power demand on the mains. The capacitor normally charges rapidly until the charging pulses become discrete, and then the charge rate falls. This point, when $E\approx 0.6E_{\max}$ is the most economical point at which to discharge.

621.316.722.1.078.3 1365
Electronic A-C Voltage Regulator—L. D. Harris. (*Electronics*, vol. 19, pp. 150–151; January, 1946.) The direct-current output from a rectifier is compared with the potential drop across a stabilizing tube. The difference is used to alter the direct-current load on another rectifier system with its transformer primary in series with the mains. The change of reactance of this winding reduces the fluctuations at the mains output terminals to about 6 per cent of their original value. Third-harmonic content of the supply is also reduced.

621.316.722.1.078.3. 1366
Stabilized D-C High-Voltage Supply—A. M. Gurewitsch and P. C. Noble. (*Gen. Elec. Rev.*, vol. 48, pp. 46–52; December, 1945.) The supply was designed for an electron-diffraction instrument. A 35-kilocycles-per-second power-oscillator output is amplified, transformed to 15 kilovolts, and rectified by means of a voltage-quadrupling circuit to give 60 kilovolts with an output of 60 watts. The filaments of the rectifiers and also the filament of the electron gun are each supplied from separate 250-kilocycles-per-second power oscillators. Automatic regulation is obtained by applying some of the output voltage to the screen of the driving oscillator. A 10 per cent change in input voltage, or a load varying from 0.5 to 1.0 milliampere, causes the output voltage to vary less than 0.1 per cent. The alternating-current ripple is about 0.05 per cent.

621.316.722.1.078.3 1367
A Voltage Regulator for X-Ray Circuits—W. P. Davey. (*Phys. Rev.*, vol. 68, p. 285; December 1–15, 1945.) Changes in the rectified mains voltage operate a relay train to a motor which moves the field rheostat of a 20-kilovolt-ampere alternator in the appropriate direction. The alternating voltage is regulated to ±0.02 volt in 110 volts. Abstract of an American Physical Society paper.

621.317.083.7+621.398 1368
New Power Operated Sensitive [meter] Recorder—P. G. Weiller. (*Elec. Ind.*, vol. 5, pp. 88–140; January, 1946.) Contact of the meter pointer with one of two graphite blocks starts a motor, through a triode and relay, which moves the block away from the pointer, and simultaneously operates a means of remote indication or control. Precautions taken avoid hunting, sticking of contacts, or interruption of operation by electrostatic forces or absorbed gases on the contacts. Any meter with a torque of 0.02 gram-centimeter or more for full-scale deflexion may be used.

621.318.42.029.6 1369
R. F. Chokes at u.h.f.—W. J. Stolze. (*Radio News*, vol. 35, pp. 54–114; January, 1946.) Chokes should have very high impedance at the working frequency, sufficiently low resistance, and the wire should have sufficient current-carrying capacity. Choke connections should be as short as possible. A design chart gives recommended numbers of turns for frequencies from 40 to 160 megacycles per second. Examples of uses for chokes are given, and the use of transmission lines as chokes is mentioned.

621.384.6 1370
100 Million Volt Electron Accelerator—(*Elec. Ind.*, vol. 4, pp. 90–168; December, 1945.) An account of the device described in 438 of February (Westendorp and Charlton).

621.386(091) 1371
X-Ray History and Development—W. D. Coolidge and E. E. Charlton. (*Elec. Eng.*, vol. 64, pp. 427–432; December, 1945.) See 770 of March. This paper also appears in *Radiology*, December, 1945.

621.386(4) 1372
50 Years of X-Ray Progress in Europe—J. H. van der Tuuk. (*Elec. Eng.*, vol. 64, pp. 444–448; December, 1945.)

621.398: 621.318.5 1373
Industrial Relay Control Circuits—Batcher. (*See* 1391.)

621.398: 621.396.662. 1374
Automatic Positioning Control Mechanisms—R. W. May and N. H. Hale. (*Elec. Ind.*, vol. 5, pp. 58–158; January, 1946.) A review of types of mechanisms suitable for rapid readjustment of the controls of multifrequency transmitters. The Collins Autotune is described in detail.

621–526 1375
Fundamental Theory of Servomechanisms [Book Review]—L. A. MacColl. D. Van Nostrand Company, Inc., New York, N. Y., $2.50. (*Elec. Ind.*, vol. 5, p. 163; February, 1946.) "It is scholarly and will well repay the expert or would-be expert for its study."

TELEVISION AND PHOTOTELEGRAPHY

621.383.8 1376
High Sensitivity Pickup—(*Elec. Ind.*, vol. 4, pp. 88–89; December, 1945.) A short account of the RCA image orthicon, a television camera tube about 100 times more sensitive than previous instruments. Electrons are emitted from a photoelectric screen, and are attracted electrostatically to a nonconducting target, where they cause the emission of secondary electrons, leaving a pattern of positive charges corresponding to the original light image. The back of the target is scanned by an electron beam that has just enough energy almost to reach the screen before being turned back to the gun by the electrostatic forces. When the beam scans a part of the target that is positively charged, sufficient electrons are attracted from the beam to neutralize the charge, leaving the returning beam correspondingly deficient. The returning beam is, therefore, modulated according to the electrical pattern on the target. It strikes the front of the electron gun, causing the emission of secondary electrons that are attracted by the plates of an electron multiplier from which the output is obtained. For another account, see *Electronics*, vol. 18, p. 330; December, 1945.

621.385.832 1377
Phosphors and Their Behavior in Television [Parts I and II]—Krushel. (*See* 1272/1273.)

621.397 1378
[U.S.] Industry Standardization Work in Television—D. B. Smith. (*Elec. Ind.*, vol. 4, pp. 192, 194; December, 1945.) A brief survey of proposals for further standardization of the television service on the lower frequency range of operation. Reference is made to three-dimensional color television. Summary of an Institute of Radio Engineers paper. See also *Electronics*, vol. 19, pp. 244–246; January, 1946.

621.397: 535.317 1379
[Optical] Lens Aberrations in Picture Projection—A. Montani. (*Elec. Ind.*, vol. 5, pp. 86, 87, 150; January, 1946.) Qualitative description of six types of aberration which should be corrected in television equipment.

621.397: 621.396.619.1 1380
Amplitude Modulator for Facsimile—Artzt. (*See* 1390.)

621.397.3: 621.396.615.17 1381
Television Sweep Oscillators—E. M. Noll. (*Radio News*, vol. 35, pp. 52–74; January, 1946.) The basic theory of sawtooth voltage generators, including the multivibrator, blocking oscillator, and gas-discharge oscillator. Part II of a series beginning with 782 of March.

621.397.5: 621.396.619.16 1382
Transmission of Television Sound on the Picture Carrier—G. L. Fredendall, K. Schlesinger, and A. C. Schroeder. (PROC. I.R.E. AND WAVES AND ELECTRONS, vol. 34, pp. 49P–61P; February, 1946.) A discussion of duplex transmission using several types of pulse modulation. "The advantages of duplex transmission are: (1) elimination of a separate sound transmitter; (2) elimination of the ambiguity and difficulty which may occur when a standard frequency-modulated sound signal is tuned in; (3) freedom of the audio output from the type of distortion which occurs in frequency-modulated receivers as a consequence of excessive drift of the frequency of the local oscillator; and (4) improvement of the phase characteristic of the picture intermediate-frequency amplifier resulting from elimination of trap circuits.

"With the exception of pulsed frequency modulation, the signal-to-noise ratios of sound in duplex systems are not so great as the ratio offered by the transmission of a standard frequency-modulated carrier. The comparison is subject to the condition that the amplitude of the frequency-modulated carrier is 0.7 of the peak amplitude of the duplex carrier. The signal-to-noise ratio of a pulsed frequency-modulated signal may equal the ratio of a standard frequency-modulated signal up to a critical distance from the transmitter, but is less at greater distance."

621.397.62 1383
Television Psychology: Is the Large Screen Essential?—B. Bellac. (*Wireless World*, vol. 52, p. 40; February, 1946.) A small, close object may subtend the same angle at the eye as a large object seen from a distance, but the convergence of the eye axes in viewing the close object gives an impression of nearness and therefore of smallness. An unpleasant impression is produced by the discrepancy between the smallness of the image and the intensity of the sound. These faults can be overcome only by a television receiver with a projection system giving an image size comparable with that of home moving pictures.

621.397.8 1384
Television for Urbanized Areas—G. Duvall. (*Radio News*, vol. 35, pp. 88–92; January, 1946.) There is no ready-made solution for the best siting of television aerials, when line-of-sight reception is impossible. Due to reflections from physical barriers, the proper orientation of the dipoles is a matter of experiment. Maximum height consistent with feeder cable cost is an over-all aim.

TRANSMISSION

621.385.3.029.63: 621.396.615.16.029.63 1385
A Vacuum-Contained Push-Pull Triode Transmitter [Type VT158]—Zahl, Gorham, and Rouse. (*See* 1403.)

621.396.61/.62+621.395.645 1386
Low Power Transmitting, Receiving, and Hailing Equipment. Type CNY.1—W. J. Morcom. (*Marconi Rev.*, vol. 8, pp. 119–124; October/December, 1945.) This transportable equipment has facilities for telephony and telegraphy transmission, reception, and hailing. The transmitter power is 5 to 8 watts on 1.5 to 9 megacycles per second. The receiver gives an output of 3.5 watts, and the audio-frequency power input to the hailing loudspeaker is 10 watts.

621.396.61: 621.396.619.018.41 1387
Concentric Line [88-108 Mc/s band] FM Transmitter for 250 W—(*Elec. Ind.*, vol. 5, pp. 78–146; February, 1946.) Description of the Transmitter Equipment Manufacturing company equipment. Use of miniature tubes and push-pull circuits reduces problems of frequency multiplication, stability, and modulation. Electromechanical tuning maintains the frequency relative to a crystal-controlled oscillator.

621.396.61.029[.58+.62 1388
Unusual Transmitter for 28–54 Mc/s—R. P. Turner. (*Radio News*, vol. 35, pp. 40–126; January, 1946.) Constructional details of a 30-watt transmitter, continuously tunable throughout the frequency band, with provisions for crystal control. The controlled oscillator works on the fundamental or second harmonic of a crystal with frequency about 7 megacycles per second. The frequency is quadrupled in the driver stage. Use of a dual beam tetrode, type 815, link-coupled to the driver stage, avoids the necessity for neutralization.

621.396.615.12 1389
Transitron Oscillator for High Stability—W. Muller. (*Elec. Ind.*, vol. 4, pp. 110–138; December, 1945.) An oscillator to cover the range 40 to 175 kilocycles per second with a stability of ±4 cycles per second between −40 and 60 degrees centigrade, and for line-voltage variations of ±25 per cent was required. Of three types considered (including phase-shift and electron-coupled oscillators), the transitron oscillator best fulfilled the requirements. A detailed description is given of the design of the circuit and of the experiments on which it was based.

621.396.619.1: 621.397 1390
Amplitude Modulator for Facsimile—M. Artzt. (*Elec. Ind.*, vol. 4, p. 172; December, 1945.) A method of modulating a wave from a resistance-capacitance-coupled oscillator at the maximum possible keying rate, with freedom from transients. Summary of U.S. Patent 2,373,737.

VACUUM TUBES AND THERMIONICS

537.525 1391
Small Perturbations of the Electric Discharge—Granovsky. (*See* 1224.)

537.533.8 1392
Erratum: Secondary Emission of Pyrex Glass—C. W. Mueller. (*Jour. Appl. Phys.*, vol. 17, p. 62; January, 1946.) Correction to the composition of the glass quoted in 3648 of 1945(Mueller).

621.38(083.72) 1393
The Tron Family—W. C. White. (*Elec. Ind.*, vol. 5, pp. 80–136; January, 1946.) A glossary of names of vacuum tubes and other electronic devices having the suffix "tron," with bibliographic references to early use of the words.

621.385+621.396.615+538.561 1394
Interchange of Energy between an Electron Beam and an Oscillating Electric Field—J. Marcum. (*Jour. Appl. Phys.*, vol. 17, pp. 4–11; January, 1946.) "Relations between various parameters are obtained which describe the behavior of an accelerated electron beam which is caused to traverse an alternating electric field. In particular, a mechanicographical means for obtaining the gain or loss of energy is described. It is shown that under the most favorable conditions a maximum of 17 per cent of the energy in the accelerated beam may be transferred to the alternating field. Application of these principles to a type of ultra-high-frequency oscillator is treated."

621.385 1395
Physical Limitations in Electron Ballistics—J. R. Pierce. (*Bell Sys. Tech. Jour.*, vol. 24, pp. 305–321; July-October, 1945.) Mainly a consideration of devices with large beam currents, dealing with the following points: electron lens aperture; distribution of initial velocities of electrons; space-charge effects; power-dissipation limits; effect of scaling down electron devices.

621.385 1396
Electron Ballistics in High-Frequency Fields—A. L. Samuel. (*Bell Sys. Tech. Jour.*, vol. 24, pp. 322–352; July/October, 1945.) The five fundamental functions of an electronic device are production of an electron beam, modulation of the beam, conversion of this modulation into a usable form, abstraction of energy from the beam, and collection of spent electrons. Conversion mechanisms in which electrons are sorted according to velocities and the "bunching" of electrons as used in magnetrons, Barkhausen tubes, diode oscillators, and klystrons are considered. The mathematical analysis of electron motions in the klystron is outlined, and diagrams given which illustrate graphically the bunching effect. The influence of space charge in modifying the bunching effect and electron paths within the magnetron is briefly discussed.

621.385 1397
Factors Determining Industrial Tube Life—J. F. Dreyer, Jr. (*Elec. Ind.*, vol. 4, pp. 94–156; December, 1945.) Apart from mechanical defects and careless handling, the normal life of a tube depends solely on the rate of cathode emission. A curve showing the relationship between emission and expected life is given, followed by a detailed discussion on methods of obtaining optimum efficiency at minimum cost.

621.385: 623.454.25 1398
Proximity Fuze Tubes—M. A. Acheson. (*Electronics*, vol. 19, pp. 228–236; January, 1946.) Summary of an Institute of Radio Engineers paper describing the special requirements and the expedients by which they were met.

621.385.029.64(43) 1399
Germany's UHF Tubes—Combined Intelligence Objectives Subcommittee. (*Elec. Ind.*, vol. 5, pp. 81–122; February, 1946.) Describes construction and design principles of velocity-modulated and magnetron tubes for continuous-wave and pulse operation on bands between 10 centimeters and 3.7 millimeters wavelength. Exploration of intense electron beams is made with pieces of carbonized paper which glow when inserted in the beam. Information taken from Combined Intelligence Objectives Subcommittee reports, index numbers 58, 59, 69, 78, and 95.

621.385.1 1400
Reflex Oscillators Utilizing Secondary Emission Current—C. C. Wang. (*Phys. Rev.*, vol. 68, p. 284; December 1–15, 1945.) To increase the power output of velocity-modulated tubes, a secondary-emission electrode is introduced to increase the beam current delivered to the gap where high-frequency energy is absorbed from the beam. The tubes have been successfully operated at 4000 megacycles per second. Abstract of an American Physical Society paper.

621.385.16.029.63/.64 1401
Cavity Magnetrons—D.G.F. (*Electronics*, vol. 19, pp. 126–131; January, 1946.) Details of the development and construction of centimetric-wave tubes used for radar. A list of types developed for pulsed operation in the L band (25 to 50 centimeters), S band (8 to 11 centimeters), and X band (3 centimeters) is given, with the power and duty-cycle ratings. Efficiency, undesired modes, magnet construction, and output matching are discussed. The Rieke

diagram showing the effect of load impedance on output power and frequency of a typical magnetron is given. Peak powers up to and beyond a megawatt have been obtained.

621.385.16.029.63/.64 1402

Theory of Magnetron Tubes and Their Uses—H. G. Shea. (*Elec. Ind.*, vol. 5, pp. 66–70; January, 1946.) A simple derivation of cavity magnetron theory, with discussion of the results and of application to the construction of standard types. Particular reference is made to mode stability and to the "strapping" of alternate barriers. Frequency/power (Rieke) diagrams, and typical operating conditions are given for the 4J36-4J41 type.

621.385.3.029.63: 621.396.615.16.029.63 1403

A Vacuum-Contained Push-Pull Triode Transmitter [Type VT158]—H. A. Zahl, J. E. Gorham, and G. F. Rouse. (Proc. I.R.E. and Waves and Electrons, vol. 1, pp. 66W–69W; February, 1946.) The resonating grid and plate circuits are contained in the vacuum and form integral parts of the grid and plate structures. The tube is used with a tuned filament line. It can oscillate in a narrow frequency band between 200 and 700 megacycles per second. It will give 200 to 300 kilowatts pulsed peak powers, and can also be used for continuous wave.

621.385.5: 539.16.08 1404

Use of 6AK5 and 954 Tubes in Ionization Chamber Pulse Amplifiers—V. L. Parsegian. (*Rev. Sci. Inst.*, vol. 17, pp. 39–40; January, 1946.) Results based on tests to obtain high signal-to-noise ratio with floating grid and with very high grid-leak operation.

621.385.5: 621.396.619 1405

Phasitron Converts from AM to FM Directly—(*Elec. Ind.*, vol. 5, pp. 78–79; January, 1946.) A horizontal circular disk of electrons from the cathode of the phasitron is modulated at the crystal-controlled carrier frequency by a grid system that bends the electron trajectories in a vertical direction so that the edge of the electron sheet follows a line that is sinusoidal in the vertical direction. The grid system is composed of a number of similar elements equally spaced around the vertical axis so that there are several wavelengths of vertical modulation around the complete electron sheet. Also, each grid element is threefold and fed with a three-phase voltage so that the modulation profile of the sheet rotates about the vertical axis. There is a coaxial cylindrical screen around the sheet, with holes punched in it at equiangular intervals, through which, on account of the rotation of the fluted electron sheet, are projected streams of electrons that vary in intensity at the carrier frequency. A coil of wire coaxial with the electron sheet carries audio-frequency current and produces an alternating magnetic field that deflects the electron trajectories in a circumferential direction, and consequently phase-modulates the streams of electrons passing through the holes in the screen. An anode outside the screen collects the projected electrons and therefore carries a current alternating at the carrier frequency and phase-modulated at the audio frequency.

621.385.5: 621.396.621.54 1406

Recent Developments in Converter Tubes—W. A. Harris and R. F. Dunn. (*Electronics*, vol. 19, pp. 240–242; January, 1946.) Description of the 6SB7Y converter which has a conversion transconductance of 0.95 milliampere per volt, and an oscillator transconductance of 8 milliamperes per volt. It is said to give improved gain and signal-to-noise ratio in the medium- and short-wave bands. Some details of operation around 100 megacycles per second are given. Summary of an Institute of Radio Engineers paper. See also *Elec. Ind.*, vol. 4, p. 81; December, 1945.

621.385.831: 621.396.619.018.41 1407

Ratio-Controlled Amplifier—C. W. Hansell. (*Elec. Ind.*, vol. 4, p. 120; December, 1945.) An amplifier tube intended for use with a balanced discriminator, avoiding the necessity of a limiter in frequency- or phase-modulation detector circuits. Summary of U.S. Patent 2,383,855.

MISCELLANEOUS

001.8: 62 1408

A Plea for the Scientific Method—L. Hoffer. (Proc. I.R.E. and Waves and Electrons, vol. 1, pp. 56W–57W; February, 1946.) The importance of critical discrimination, proper classification of data, scientific technique, and pure research in engineering are outlined.

001.89 1409

Science and the Government—H. M. Kilgore. (*Science*, vol. 102, pp. 630–638; December 21, 1945.) Discussion of a proposal to set up a National Scientific Research Foundation in the United States of America, in the form of a government agency, dealing with research into all problems related to national welfare.

001.891: 6(410) 1410

Alliance of Industry and Scientific Research in Great Britain—B. J. A. Bard. (*Science*, vol. 103, pp. 6–8; January 4, 1946.) Present plans for closer liaison include endowments and scholarships to be offered to the universities by industry, interchange of staff, and joint research councils.

519.283. 1411

Statistical Methods in Quality Control—VII—A.I.E.E. Subcommittee on Educational Activities. (*Elec. Eng.*, vol. 64, pp. 448–450; December, 1945.) The use of control charts and the analysis of samples in a manufacturing process to determine factors which might need correction. For previous parts, see 805 of March. See also 1412 below.

519.283 1412

Statistical Methods in Quality Control—IX—A.I.E.E. Subcommittee on Educational Activities. (*Elec. Eng.* vol. 65, pp. 81–83; February, 1946.) Discussion of acceptance sampling based on the method of attributes, including single sampling, double sampling, and multiple sampling. The "operating characteristics" are plotted to compare the various methods. See also 1411 above.

62 1413

Progress Depends on Sound Engineering—J. A. Stobbe. (*Elec. Ind.*, vol. 5, pp. 72–73; February, 1946.) Emphasizes the need for close contact between engineer and consumer, and for designing for reduction of production costs.

621.3.012.3: 621.3.081.4 1414

Decibel Conversion Chart—Miedke. (*See* 1281.)

621.3.085.6+321.3.017.72 1415

Heat Dissipation from Cabinets for Electrical Instruments—H. C. Littlejohn. (*Gen. Rad. Exp.*, vol. 20, pp. 4–5; January, 1946.) A table is given showing the relative heat-dissipation properties of various materials. The most efficient dissipator is a metal case with an internal and external dull-black finish.

621.38: 621.317.2 1416

A Laboratory for Basic Electronics—P. M. Honnell and W. E. Strohm. (*Elec. Eng.*, vol. 65, pp. 75–80; February, 1946.) A description of the 140-position electronics laboratory installed at the U. S. Military Academy. A central switchboard distributes alternating or direct voltage, including audio and radio frequency up to 18 megacycles per second, to any of twelve benches, each of which has several student positions equipped with its own switchboard. Protective measures include automatic isolating of small sections to facilitate fault tracing.

621.394/.395].653+531.4+539.62 1417

The Physics of Rubbing Surfaces—Bowden. (*See* 1219.)

621.396/.397](058.7) 1418

1945 Electronic Engineering Directory—(*Elec. Ind.*, vol. 4, December, 1945.) A 56-page directory of United States sources of supply of radio and allied equipment. A supplement giving names of patent attorneys and consulting engineers appears in *Elec. Ind.*, vol. 5, pp. 98, 100; January, 1946.

621.396.62.017.72 1419

Ventilation Problems—W. Tusting. (*Wireless World*, vol. 52, pp. 72–75; March, 1946.) Suggests that the need for dissipating the heat (60 to 200 watts) generated by radio receivers is not always given due consideration in the early design stage. Excessive temperature rise may reduce component life. It is also liable to cause considerable frequency drift. The provision of unimpeded channels for air flow around tubes is the chief recommendation.

621.396.9: 061.6 1420

History and Activities of the Radiation Laboratory of the Massachusetts Institute of Technology—DuBridge. (*See* 1251.)

621.38 1421

Electronics for Engineers [Book Review]—J. Markus and V. Zeluff (editors). McGraw-Hill Book Co., New York, N. Y., 1945, 390 pp., $6.00 (*Elec. Eng.*, vol. 65, p. 98; February, 1946.) A collection of 142 articles, reference sheets, charts, and graphs reprinted from *Electronics*.

Capacitor Quality . . .

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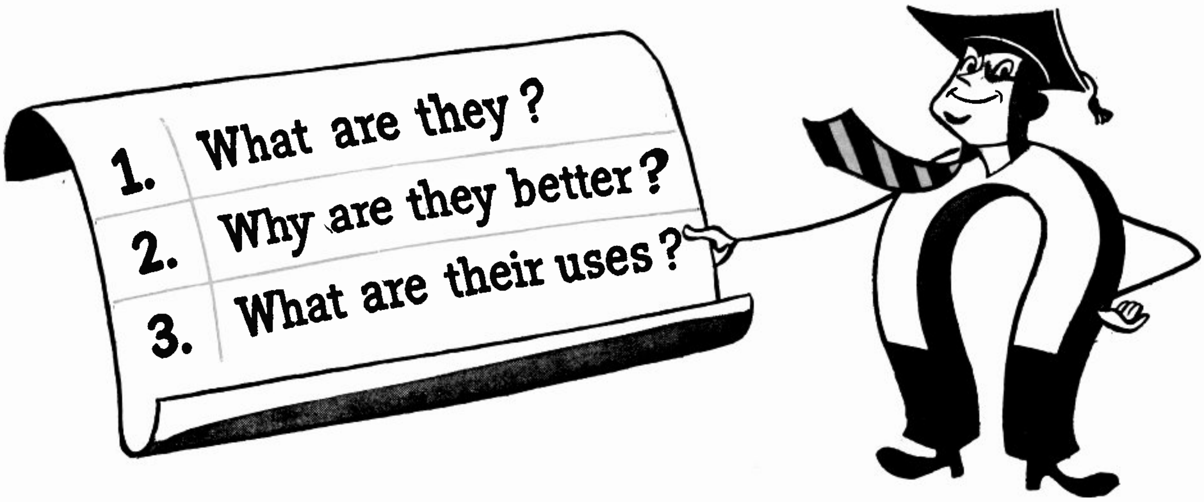
A-1

The 3 "most-asked" questions about Carbonyl Iron Powders



For wartime uses, design engineers asked these three questions.

In peacetime, as design engineers plan for peacetime equipment, the same questions are asked.

"What are they?"

G.A.F. Carbonyl Iron Powders are obtained by thermal decomposition of iron penta-carbonyl. There are five different grades in production, designated as "L," "C," "E," "TH," and "SF" Powder. Each of these five types of iron powder is obtained by special processing methods and has its special field of application.

The particles making up the powders "E," "TH," and "SF" are spherical with a characteristic structure of concentric shells. The particles of "L" and "C" are made up of homogeneous spheres and agglomerates.

Their weight-average diameter, their total iron contents, and their carbon contents are given in the table at upper right.

"Why are they better?"

Carbonyl Iron Powders are better because of their unique spherical shape, shell structure, particle size distribution, high degree of purity and freedom from stress.

Their stability against magnetic shock, temperature changes, and time (aging) is of the highest order.

Permeabilities range up to 70 with low eddy-current losses. Q values are the highest obtainable because of extremely small eddy-current and hysteresis losses.

Carbonyl Iron Powders are better as electromagnetic material over the entire communication frequency spectrum.

A set of relative Q values for the five powder grades is given in the graph on the other page to show the conventional frequency range for each grade.

"What are their uses?"

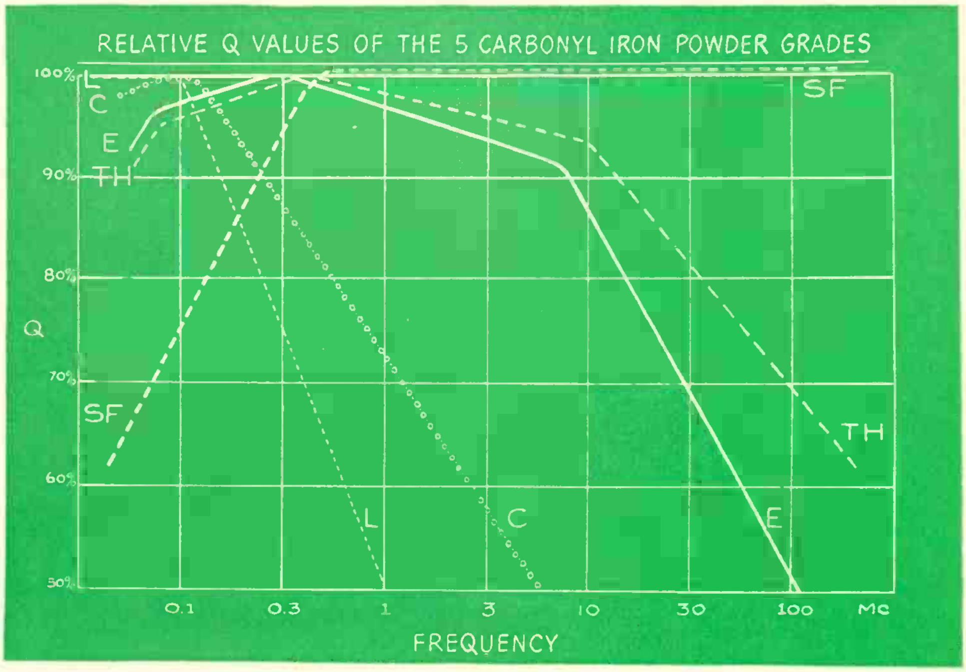
Carbonyl Iron Powders are used for electromagnetic cores and structures for widely different purposes. Five typical applications are shown on the chart at bottom of other page.

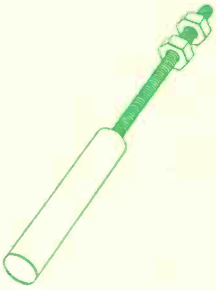
"L" and "C" powders are also used as powder metallurgical material because of their low sintering temperatures, high tensile strengths, and other very desirable qualities. Sintering begins below 500°C and tensile strengths reach 150,000 psi. Compacts can be made having regular pronounced porosity to function as a spongy mass. Compacts can also be made of highest density for excellent magnetic properties.

Further information can be obtained from the Special Products Sales Dept., General Aniline & Film Corporation, 270 Park Avenue, New York 17, N. Y.

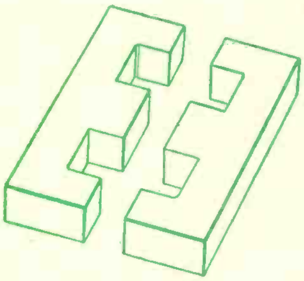
Diameters and Chemical Composition of the 5 Carbonyl Iron Powder Grades

Carbonyl Iron Grade	Weight-Average Diameter Microns	Total Fe Content %	Total Carbon Content %
L	20	99.7-99.9	0.005-0.03
C	10	99.5-99.8	0.03 -0.12
E	8	97.9-98.3	0.65 -0.80
TH	5	98.1-98.5	0.5 -0.6
SF	3	98.0-98.3	0.5 -0.6

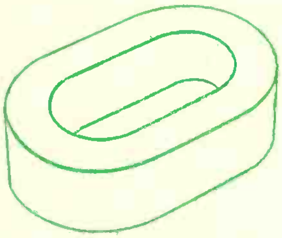




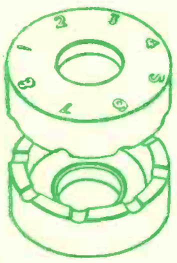
"L" Type Powder used in cores for permeability tuning.



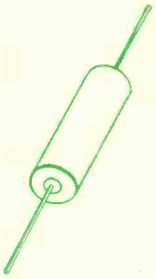
"C" Type Powder for E-cores in filter coils.



For antenna coils, "E" Type Powder used in cores.



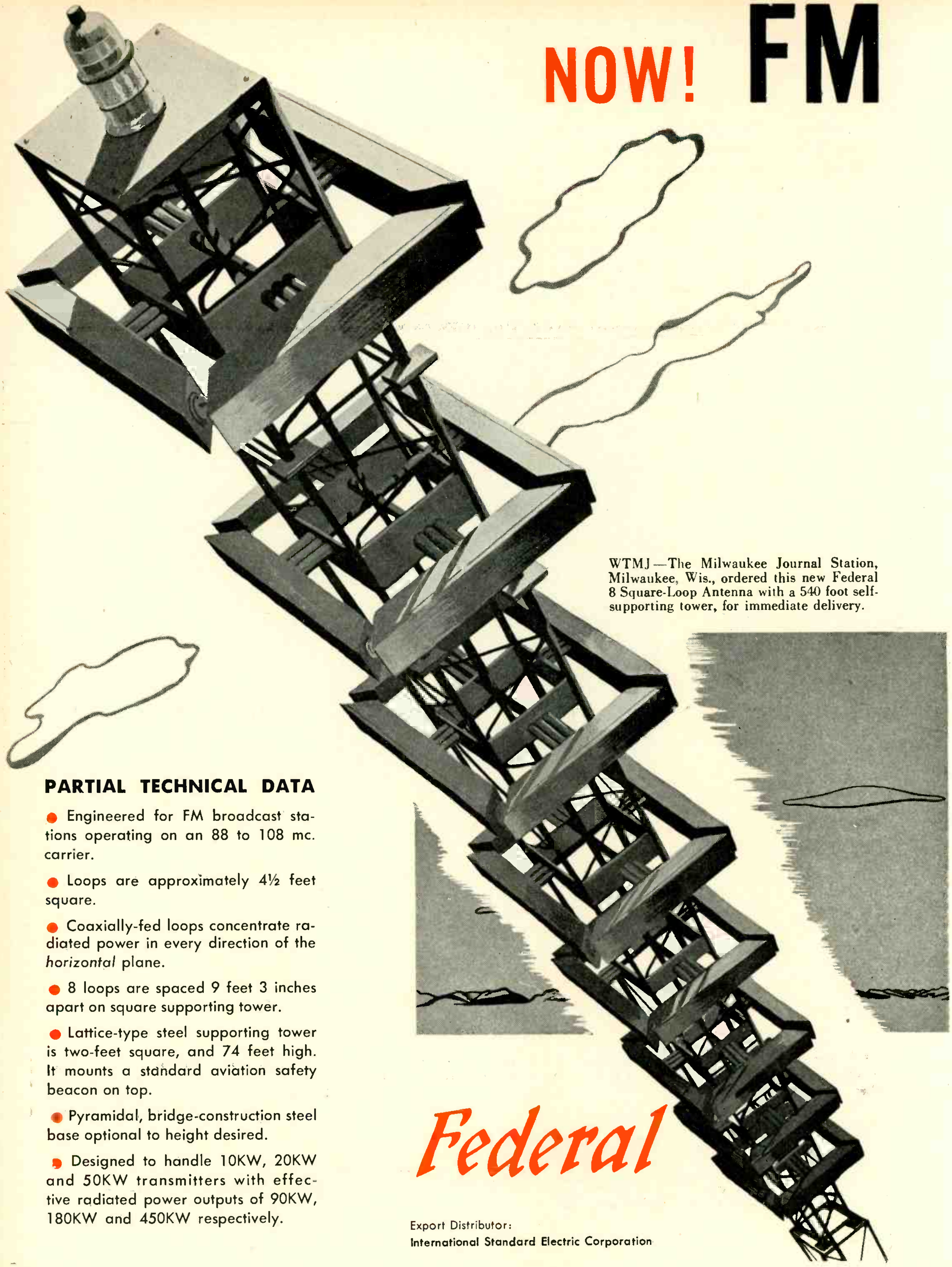
"TH" Type Powder is employed for cup shields in coils.



One use of "SF" Type Powder is in high frequency choke cores (with sealed-in leads).

G.A.F. CARBONYL IRON POWDERS

NOW! FM



WTMJ—The Milwaukee Journal Station, Milwaukee, Wis., ordered this new Federal 8 Square-Loop Antenna with a 540 foot self-supporting tower, for immediate delivery.

PARTIAL TECHNICAL DATA

- Engineered for FM broadcast stations operating on an 88 to 108 mc. carrier.
- Loops are approximately 4½ feet square.
- Coaxially-fed loops concentrate radiated power in every direction of the *horizontal* plane.
- 8 loops are spaced 9 feet 3 inches apart on square supporting tower.
- Lattice-type steel supporting tower is two-feet square, and 74 feet high. It mounts a standard aviation safety beacon on top.
- Pyramidal, bridge-construction steel base optional to height desired.
- Designed to handle 10KW, 20KW and 50KW transmitters with effective radiated power outputs of 90KW, 180KW and 450KW respectively.

Federal

Export Distributor:
International Standard Electric Corporation

ANTENNA WITH NOMINAL POWER GAIN OF 9!

FEDERAL's 8 SQUARE-LOOP ANTENNA PROVIDES 90KW EFFECTIVE POWER OUTPUT WITH A 10KW TRANSMITTER... 180KW WITH A 20KW TRANSMITTER...450KW WITH A 50KW TRANSMITTER!

HERE IS STILL ANOTHER EXAMPLE of Federal's leadership in the entire field of FM . . . an 8-loop antenna with the highest power gain ever available in the FM broadcast service.

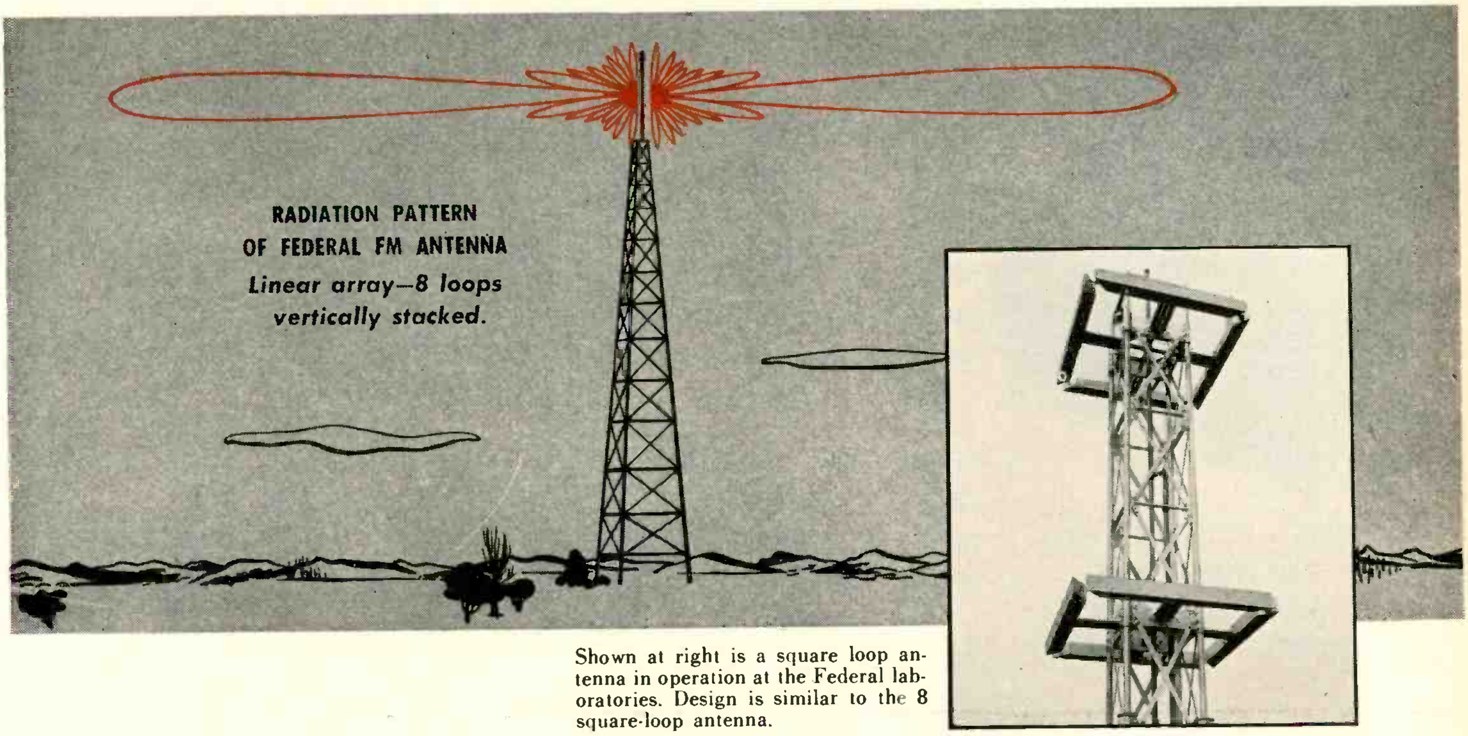
It radiates horizontally polarized waves so highly directive that very little energy is lost to useless ground or sky wave. Thus, with a power gain of 9, you can now get an effective power output of *90KW with a 10KW transmitter; 180KW with a 20KW transmitter and 450KW with a 50KW transmitter!* This not only means a great saving on the cost of original equipment, but important economies of operation as well.

Be prepared for future FCC action increasing the effective radiated power!

One antenna is built for use over the entire FM range . . . 88 to 108 megacycles. Only one predetermined stub adjustment per loop changes it for any frequency in this band. Also, antenna array may be fed in two sections with separate coaxial lines to allow for emergency auxiliary operation.

Structurally, the tower is designed not to disturb the circular pattern of the antenna's radiation . . . is supported on a rugged, pyramidal base. The entire unit withstands high wind velocities and heavy icing loads.

Coming at a time when the FCC has given the green light to FM station construction, this remarkable new antenna is another contribution to the advancement of FM transmission . . . part of the "completely packaged service" which Federal now makes available. A Federal engineer will be glad to give you full details.



RADIATION PATTERN OF FEDERAL FM ANTENNA
Linear array—8 loops vertically stacked.

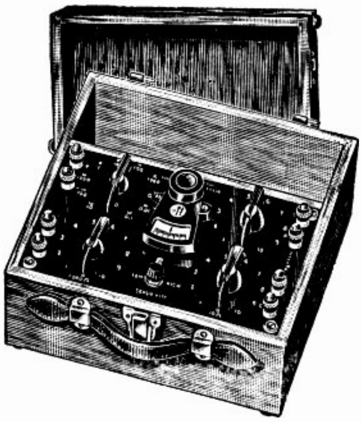
Shown at right is a square loop antenna in operation at the Federal laboratories. Design is similar to the 8 square-loop antenna.

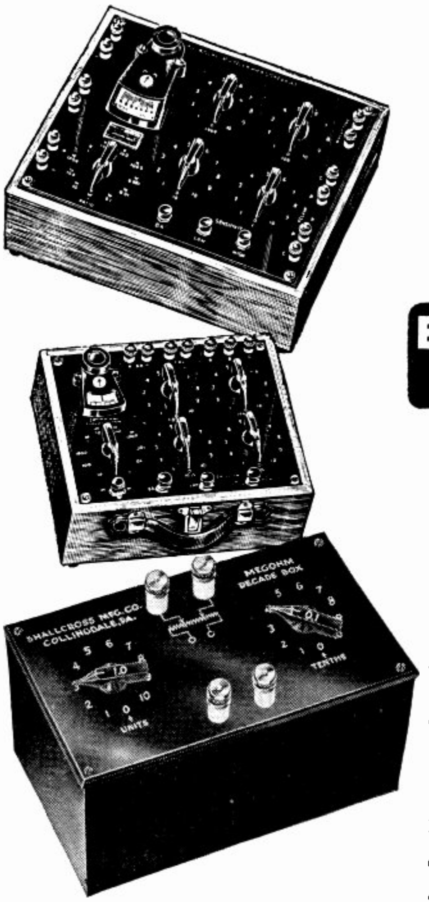
Telephone and Radio Corporation

Newark 1, New Jersey

AN IT&T ASSOCIATE

FEDERAL TELEPHONE & RADIO FTR





SECTION MEETINGS

Atlanta

"The Phasitron and Its Operation," by J. M. Comer, Jr., General Electric Company; March 15, 1946.

Boston

"Broad-Band Antennas," by Andrew Alford, Consulting Engineer; April 26, 1946.

Chicago

"Relative to the Betatron," by Donald W. Kerst, University of Illinois; April 13, 1946.

"New Slot Antenna," by Edward C. Jordan, University of Illinois; April 13, 1946.

"Radio Communications—20 Kilocycles to 2000 Megacycles," by C. W. Hansell, RCA Laboratories; April 19, 1946.

"Microwave Developments," by W. G. Hawkins, Sperry Gyroscope Company; April 19, 1946.

Cincinnati

"Deflection-Type High-Voltage Supplies for Television Receivers," by Madison Cawein, The Farnsworth Company; April 16, 1946.

Cleveland

"35-Millimeter Television Projection," by E. D. Cook, General Electric Company; April 25, 1946.

Columbus

"Generation of Centimeter Waves," by Homer Hagstrom, Bell Telephone Laboratories; March 19, 1946.

Dallas—Ft. Worth

"Radar for Bombing," by G. R. Frantz, Bell Telephone Laboratories; April 12, 1946.

Dayton

"Television Equipment for Guided Missiles," by C. J. Marshall and Leonhard Katz, Air Matériel Command; April 18, 1946.

"Modulation Measurements of Low-Level Carriers," by L. A. Regnier, J. C. Noble and Seymour Krevsky, Air Matérial Command; April 18, 1946.

"Aircraft Radio and Weather," by E. L. Cleveland, Air Matériel Command; April 18, 1946.

"Wire versus Disk Recorders for Military Aircraft," by Harry Schecter, Air Matériel Command; April 18, 1946.

Election of Officers, April 18, 1946.

Detroit

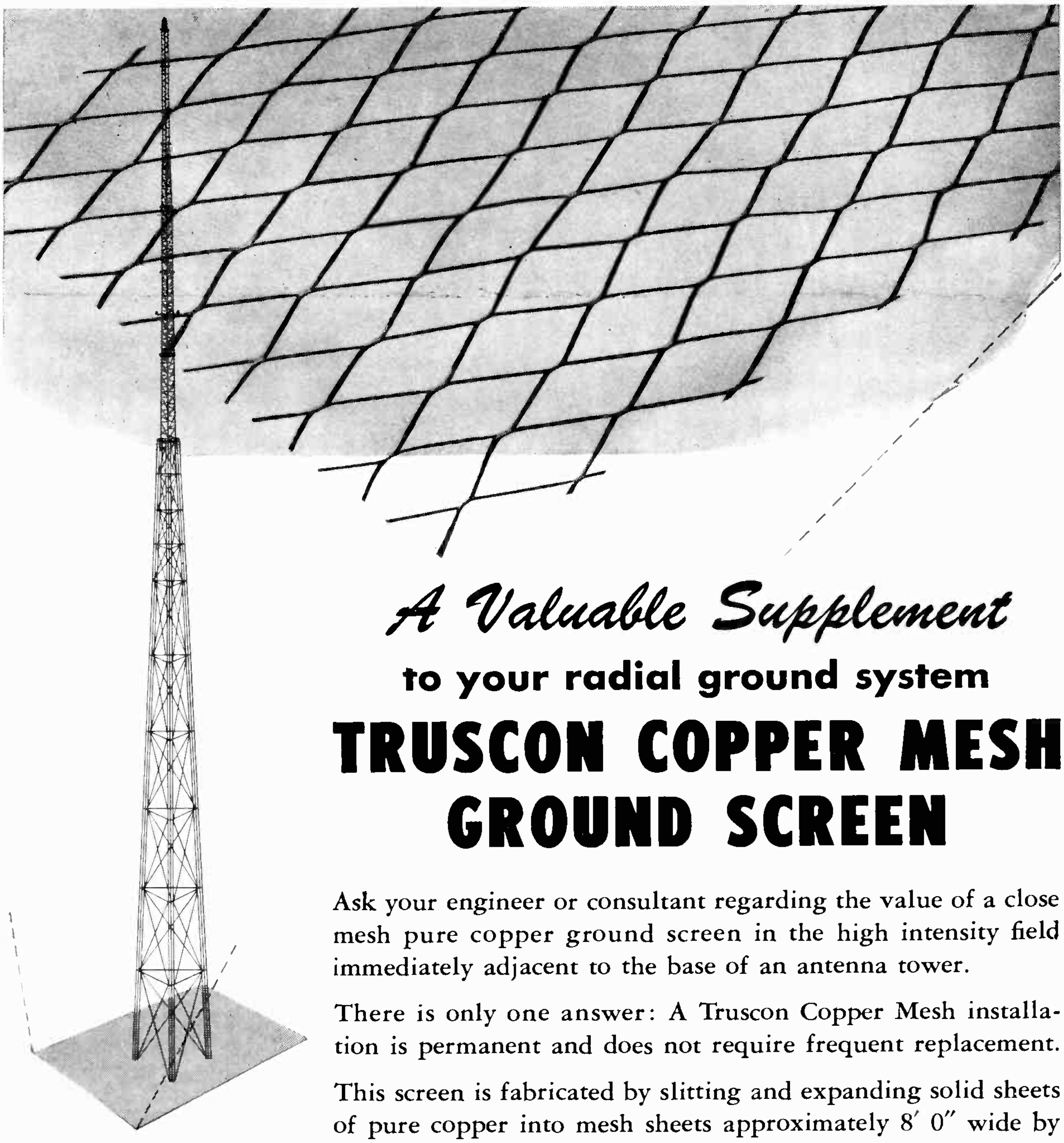
"Operation of 'ABSIE'," by R. T. Pennebaker, Station WWJ; April 19, 1946.

Houston

"Radar for Bombing," by G. R. Frantz, Bell Telephone Laboratories; April 9, 1946.

"The Development of the Proximity Fuze," by W. H. Carter, Jr., The Schlumberger Well Surveying Corporation; April 16, 1946.

(Continued on page 40A)



A Valuable Supplement

to your radial ground system

TRUSCON COPPER MESH GROUND SCREEN

Ask your engineer or consultant regarding the value of a close mesh pure copper ground screen in the high intensity field immediately adjacent to the base of an antenna tower.

There is only one answer: A Truscon Copper Mesh installation is permanent and does not require frequent replacement.

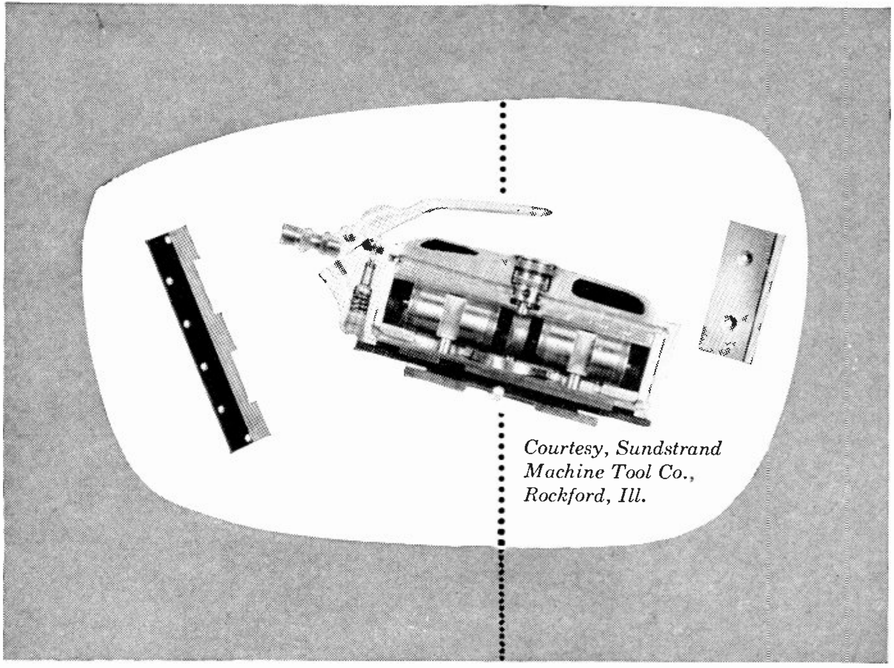
This screen is fabricated by slitting and expanding solid sheets of pure copper into mesh sheets approximately 8′ 0″ wide by 24′ 0″ long. The usual arrangement at the base of a radio tower consists of twelve sheets with edges connected by means of brazing to form a screen 48′ 0″ square.

Truscon Copper Mesh Ground Screen is available from stock. Obtain prices from our nearest sales office or write our home office at Youngstown, Ohio.

Truscon Radio Towers, too, are now available.

Manufacturers of a Complete Line of Self-Supporting Radio Towers . . . Uniform Cross-Section Guyed Radio Towers . . . Copper Mesh Ground Screen . . . Steel Building Products.

TRUSCON STEEL COMPANY
YOUNGSTOWN 1, OHIO • Subsidiary of Republic Steel Corporation



SECTION MEETINGS

(Continued from page 38A)

LONDON

"Electron-Microscope Technical Details," by S. G. Ellis, University of Toronto; February 22, 1946.

"Principles and Applications of Induction Heating," by D. R. Hay, University of Western Ontario; March 15, 1946.

"An Improved Vacuum-Tube Voltmeter," by G. Lang, University of Western Ontario; March 13, 1946.

"Pulse-Time Modulation," by W. W. Loucks, University of Western Ontario; March 15, 1946.

"Pulse-Time Modulation," by L. Libby, Federal Radio and Telephone Company; April 3, 1946.

LOS ANGELES

"Theory and Application of Intermodulation Tests," by J. K. Hilliard, Altec-Lansing Company; March 19, 1946.

"Recent Developments at Princeton Laboratories," by Harry Olsen and Vladimir Zworykin, RCA Laboratories; March 26, 1946.

MONTREAL

"Transatlantic Aeronautical Communication and Navigation," by S. S. Stevens, Trans-Canada Air Lines; April 10, 1946.

"Applications of Radio in Geophysical Prospecting," by H. G. I. Watson, McGill University; April 24, 1946.

Election of Officers, April 24, 1946.

PHILADELPHIA

"Technical Aspects of the ENIAC," by J. W. Mauchly, Moore School of Electrical Engineering, University of Pennsylvania; April 4, 1946.

"Technical Aspects of the ENIAC," by J. P. Eckert, Jr., University of Pennsylvania; April 4, 1946

PITTSBURGH

"Pulse-Time-Modulated Multiplex Radio-Relay Terminal Equipment," by D. D. Grieg, Federal Telecommunications Laboratories; March 11, 1946.

ROCHESTER

"Television Equipment for Guided Missiles," by C. J. Marshall and Leonhard Katz, Air Matériel Command; April 11, 1946.

ST. LOUIS

"Electronic Applications in Medical Research," by G. M. Schoepfle, Washington University Medical School; April 26, 1946.

SAN DIEGO

"A New Frequency-Modulation Frequency-Control Circuit," by W. U. Dent, Westinghouse Electric Company; April 3, 1946

SAN FRANCISCO

"The Phasitron and Its Use in Frequency-Modulation Transmitters," by F. P. Barnes, General Eelectric Company; February 13, 1946.

(Continued on page 42A)

Type 710-A

370 to 560 Mc

IN STOCK... for immediate delivery!

Type 734-A

1200 to 3750 Mc

RCA Signal Generators for u-h-f jobs

These signal generators may just fill the bill for some of your ultra-high-frequency development work.

The Type 710-A provides an r-f signal of a known frequency and amplitude for easily obtaining the data needed to check the performance of high-frequency devices. This instrument provides smooth and complete attenuation throughout its range, plus precision frequency control.

Output frequency: 370 to 560 megacycles—just right for citizen's radiophone and other experimental and laboratory work within these frequencies. *Output voltage:* 2 microvolts to 0.09 volt. *Amplitude modulation available:* 400 cycles ± 5 per cent, at modulation of 50 per cent maximum. Controls are provided for adjusting the carrier level, modulation, attenuation, and frequency.

The Type 734-A has been widely used for testing and adjusting radar equipment. It will prove an accurate and handy device for testing any equipment within the following band:

Output frequency: 1200 to 3750 megacycles or 25 to 8 centimeters. *Output voltage:* 1 microvolt to 0.2 volt. *Tube complement:* one 707-B—r-f oscillator, one 6J5—synchronizing amplifier, one 884—pulse-rate oscillator, one 6SN7-GT—multivibrator, one 6AG7 and one 6AC7—pulsers, two 6AC7—voltage controls, one 6J5—shaper, one 6AG7—keyer, two 6X5G and two 5Z4—power rectifiers, four VR-150-30—regulators.

These signal generators are available for immediate shipment—as long as stock lasts.

PLACE YOUR ORDER NOW!

Radio Corporation of America
Dept. 67-F, Test & Measuring Equipment Section
Camden, New Jersey

Please reserve...... (no. of units) Type..... RCA signal generators pending additional technical and price information from you. We are interested in using these instruments for the following application:

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Name__________________________Title__________

Company__________________________________

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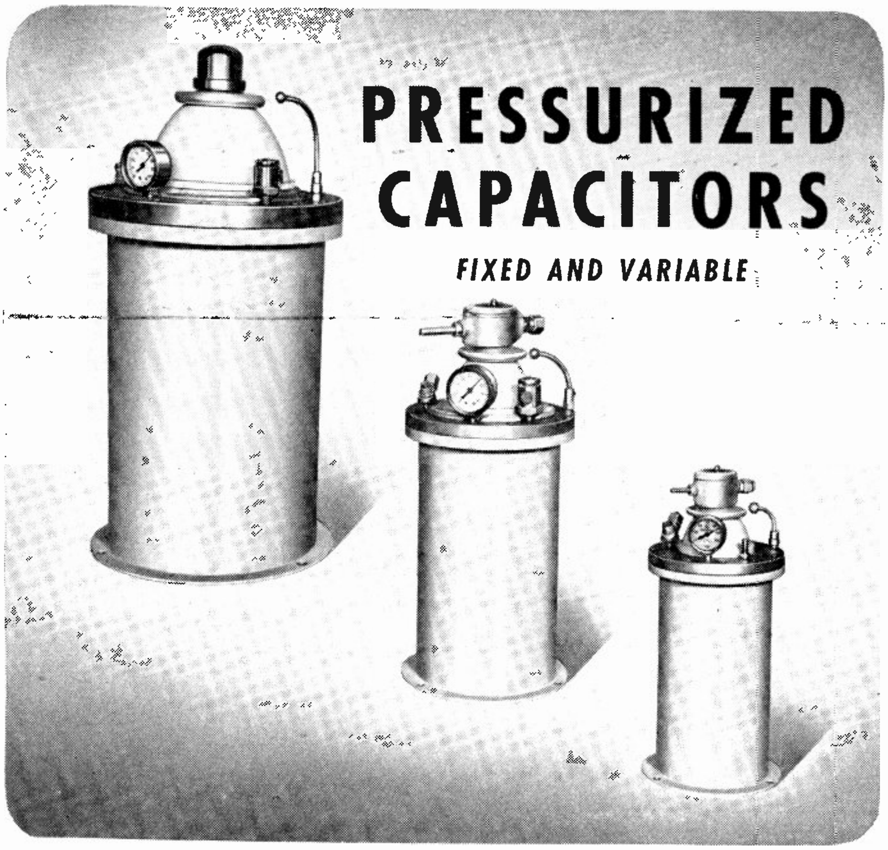
RCA

TEST AND MEASURING EQUIPMENT

RADIO CORPORATION of AMERICA

ENGINEERING PRODUCTS DEPARTMENT
CAMDEN, N.J.



SECTION MEETINGS

(Continued from page 40A)

"Radar Countermeasures," by F. E. Terman, Stanford University; March 1, 1946.

"Aircraft Use of Loran Radio Equipment," including display of equipment and Army training film, by W. H. Queen, United Air Lines; April 3, 1946.

"Fundamental Aspects of Color in Television and the Use of Ultra-High Frequencies for Television Broadcasting," by P. C. Goldmark, Columbia Broadcasting System; April 22, 1946.

TORONTO

"The Role of the Ionosphere in Radio Communication," by N. Rostoker, University of Toronto; February 25, 1946.

"Cathode Follower," by G. F. G. Weedon, University of Toronto; February 25, 1946.

"Vacuum-Tube Voltmeters," by G. R. Slemon, University of Toronto; February 25, 1946.

"Some Factors Involved in Sound Reproduction," by H. Goldin, Dominion Sound Equipments, Ltd.; March 25, 1946.

SUBSECTIONS

SOUTH BEND

"History, Development, and Use of Coaxial Cable," by R. Krueger, American Phenolic Company; January 17, 1946.

"Review of Communications in The China-Burma-India Theater," by W. F. Soules, Electro-Voice Corporation; February 28, 1946.

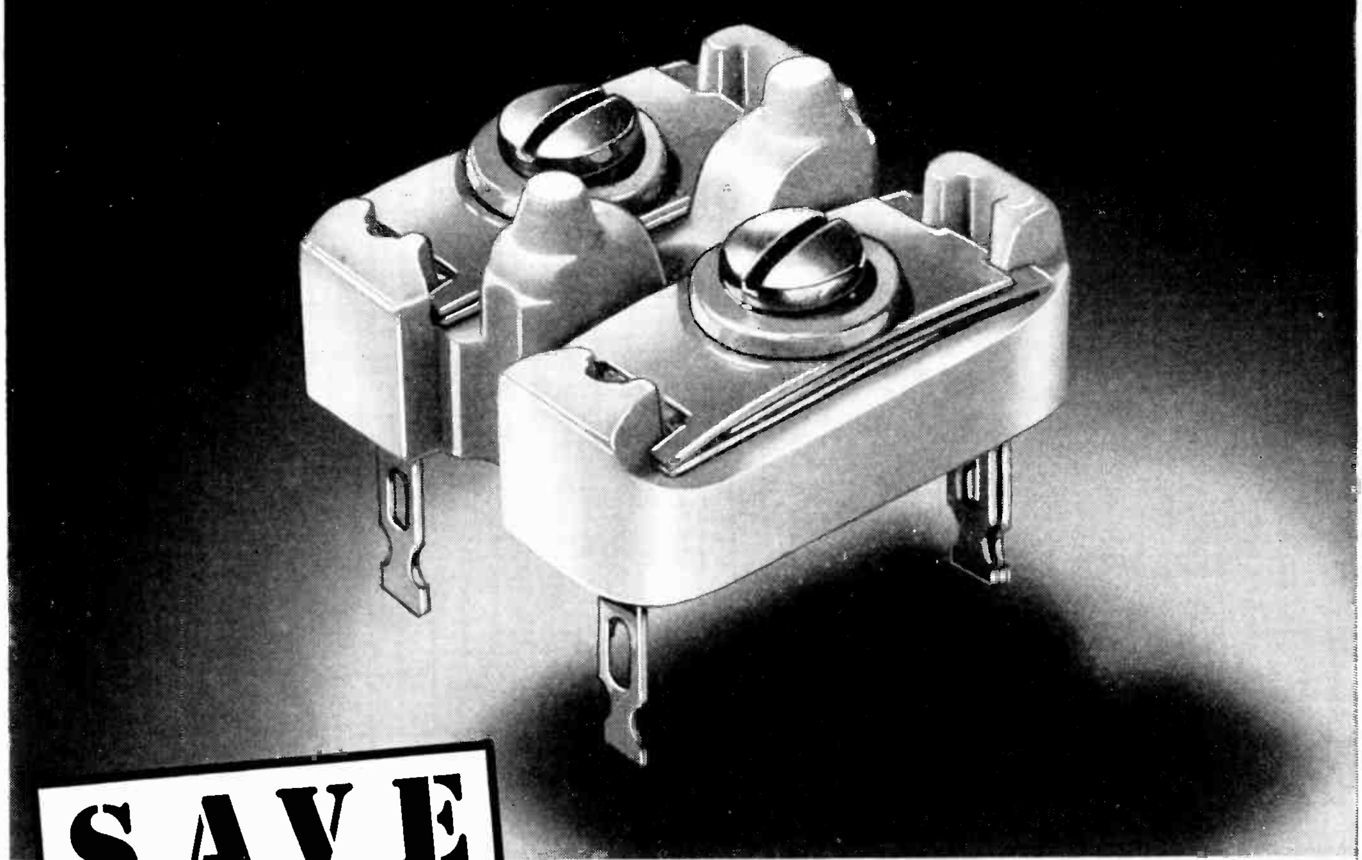
MEMBERSHIP

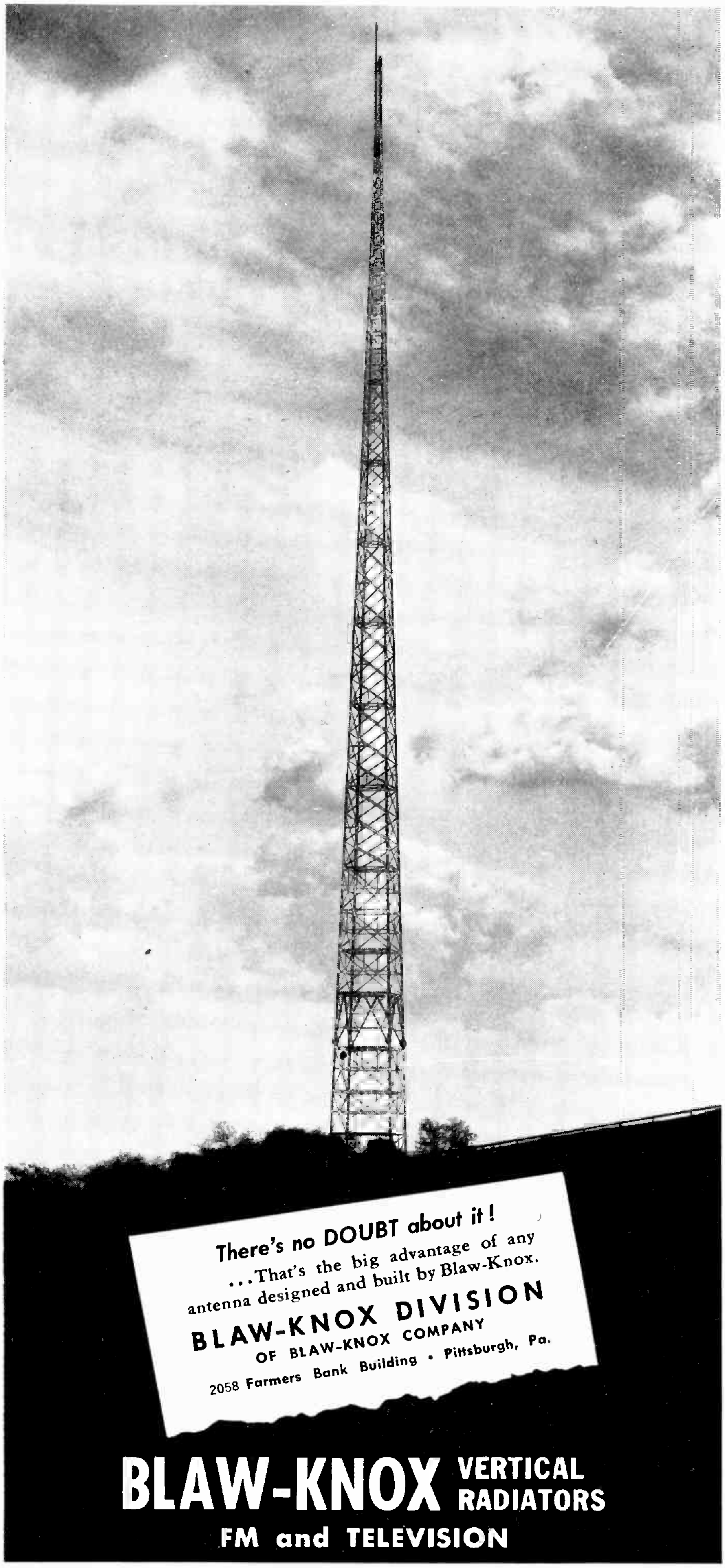
The following transfers and admissions were approved on May 1, 1946:

Transfer to Senior Member

Bossart, P. N., Union Switch and Signal Co., Swissvale, Pittsburgh 18, Pa.
Briggs, M. R., 34 Holmehurst Ave., Catonsville 28, Md.
Brownell, G. T., Majestic Radio and Television Corp., St. Charles, Ill.
Campbell, R. D., Room 1705-A, 195 Broadway, New York 7, N. Y.
Coles, F. A., 45 Christopher St., New York 14, N. Y.
Conron, W. H., 322 Estaugh Ave., Haddonfield, N. J.
Crawford, A. B., Box 107, Red Bank, N. J.
Farel, V. M., RCA International Division, 745 Fifth Ave., New York 22, N. Y.
Fischer, H. B., 463 West St., New York 14, N. Y.
Gano, A. S., 38 Cummings Ave., White Plains, N. Y.

(Continued on page 44A)





MEMBERSHIP

(Continued from page 42A)

Ginzton, E. L., 3 Raymond Court, Garden City, L. I., N. Y.
Hammann, P. L., Bell Telephone Laboratories, Whippany, N. J.
Hollingsworth, L. M., 36 Highland Ave., Cambridge 39, Mass.
Hunter, T. A., 1164 E. Court St., Iowa City, Iowa
Jaffe, D. L., Polarad Electronics Co., 135 Liberty St., New York, N. Y.
Nevitt, H. J. B., 3311—82 St., Jackson Heights, L. I., N. Y.
O'Neill, G. D., 34-10 Linden Pl., Flushing, L. I., N. Y.
Peterson, G., Box 1360, Bartlesville, Okla.
Pierce, J. R., Bell Telephone Laboratories, Inc., 463 West St., New York 14, N. Y.
Price, L. M., Radio Valve Company of Canada, 189 Dufferin St., Toronto 1, Ont., Canada
Reintjes, J. F., 354 Fourth Ave., Troy, N. Y.
Siemens, R. H., Avenida Forest 1535, Buenos Aires, Argentina
Smith, P. C., 179 Ido Ave., Akron 1, Ohio
Stout, G. P., 324 Broadmoor Rd., Baltimore 12, Md.
Waynick, A. H., 423 S. Pugh. State College, Pa.
Zahl, H. A., 320 Bath Ave., Long Branch, N. J.

Admission to Senior Member

Allsop, R. C., 30 Trafalgar Ave., Roseville, Sydney, New South Wales, Australia
Arditi, M., 157 W. 57 St., New York 19, N. Y.
Brand, P. M., 27 Mill Cove, Lambton Mills, Toronto 9, Ont., Canada
Dixon, G. P., International Telephone and Telegraph Corp., 67 Broad St., New York 4, N. Y.
Frantz, G. R., 463 West St., New York 14, N. Y.
Gillson, M. H., 19 Olyphant Dr., Morristown, N. J.
Hanson, G. N., Meadow Lane, North Shore Acres, Glen Cove, L. I., N. Y
Kohlhaas, H. T., 67 Broad St., New York 4, N. Y.
Lubkin, S., 1601 Mayland St., Philadelphia 38, Pa.
Wagenseil, W., 101 Monterey Ave., Pelham 65, N. Y.

Transfer to Member

Begley, W. W., 1413—21 St., N.W., Washington 6, D. C.
Bennett, R. M., Jr., 7443 Cromwell Dr., Clayton, Mo.
Berkley, J. B., Bureau of Ships, Navy Department, Washington 25, D. C.
Brokaw, H. R., 2553 Montrose Ave., Montrose, Calif.
Broman, H. F., 1236 New York Ave., Brooklyn 3, N. Y.
Clewes, T. W., 202 Frederick St., Kitchener, Ont., Canada

(Continued on page 46A)

New!

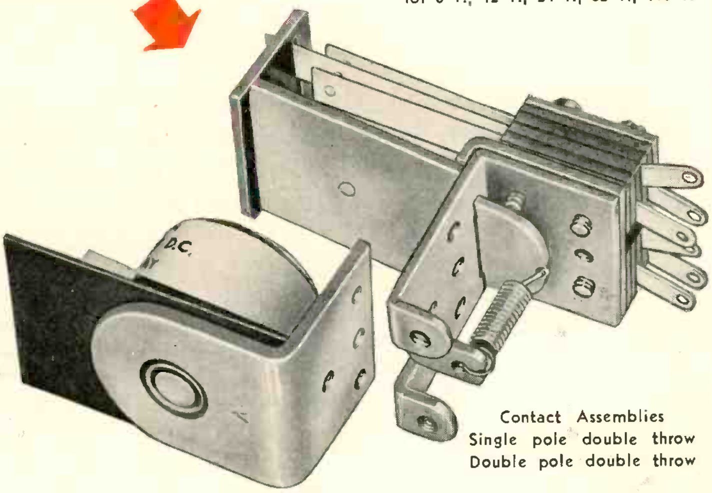
Series 200

A RELAY BY GUARDIAN with *Interchangeable Coils*

BUILT IN TWO PARTS

★ Two basic parts—a coil assembly and a contact assembly—comprise this simple, yet versatile relay. The coil assembly consists of the coil and field piece. The contact assembly consists of switch blades, armature, return spring, and mounting bracket. The coil and contact assembly are easily aligned by two locator pins on the back end of the contact assembly which fit into two holes on the coil assembly. They are then rigidly held together with the two screws and lock washers. Assembly takes only a few seconds and requires no adjustment on factory built units.

A. C. Coil Assemblies available for 6 v., 12 v., 24 v., 115 v.
D. C. Coil Assemblies available for 6 v., 12 v., 24 v., 32 v., 110 v.



Contact Assemblies
Single pole double throw
Double pole double throw

Series 200 Relay

On Sale at Your nearest jobber NOW!

See it today! . . . this amazing new relay with interchangeable coils. See how you can operate it on any of nine different a-c or d-c voltages—simply by changing the coil. Ideal for experimenters, inventors, engineers.


New
A NEW RELAY BY GUARDIAN with an *Interchangeable Coil*
GUARDIAN ELECTRIC

TWO CONTACT ASSEMBLIES

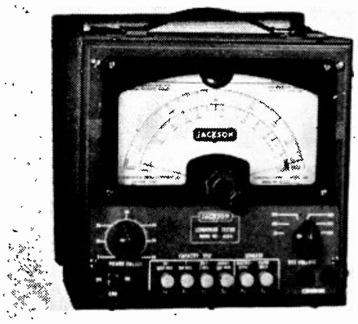
The Series 200 is available with a single pole double throw, or a double pole double throw contact assembly. In addition, a set of Series 200 Contact Switch Parts, which you can buy separately, enables you to build dozens of other combinations. Instructions in each box.

NINE COIL ASSEMBLIES

Four a-c coils and five d-c coils are available. Interchangeability of coils enables you to operate the Series 200 relay on one voltage or current and change it over to operate on another type simply by changing coils.

Your jobber has this sensational new relay on sale now. Ask him about it. Or write for descriptive bulletin.

GUARDIAN ELECTRIC
1628 G W. WALNUT STREET CHICAGO 12, ILLINOIS
A COMPLETE LINE OF RELAYS SERVING AMERICAN INDUSTRY



MEMBERSHIP

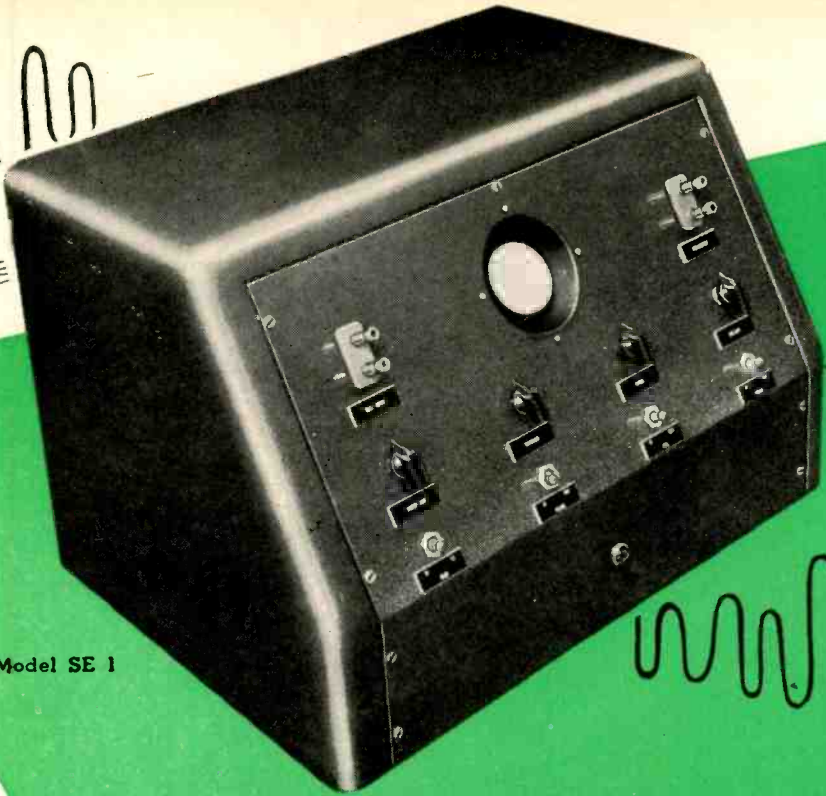
(Continued from page 44A)

Cunniff, T. W., 83 Second Ave., Newark 4, N. J.
dePasquale, R. H., 1475 Broadway, New York, N. Y.
Ducore, H., 404 S. Atkins Ave., Neptune, N. J.
Duerden, F., 112 Springfield Park Ave., Chelmsford, Essex, England
Eichwald, B., 2054 E. 21 St., Brooklyn 29, N. Y.
Hedberg, C. A., 83 Center Ave., Chatham, N. J.
Heister, C. F., 809 U. S. Court House, Federal Communications Commission, Kansas City 6, Mo.
Henderson, A. B., 9 Cushing Ave., Dayton 9, Ohio
Higgins, F. V., 5716—26 St., N., Arlington, Va.
Holets, L. L., 618—32 St., N.E., Cedar Rapids, Iowa
Holetz, A. C., 219-11—118 Ave., St. Albans 11, L. I., N. Y.
Johnson, P. B., 200 McKinley Dr., Belleville, Ill.
Kamm, G. N., 35 Conant Hall, Harvard University, Cambridge 38, Mass.
Laporte, J. M., Box 411, Sackville, N. B., Canada
Martel, C. W., 6 First St., Chelmsford, Mass.
McCoy, R. E., 5607 N. E. Garfield Ave., Portland 11, Ore.
McLeish, C. W., RFD 1, Billings Bridge, Ont., Canada
Mounce, G. R., Billings Bridge, Ont., Canada
Oliver, B. M., Bell Telephone Laboratories, 463 West St., New York 14, N. Y.
Paine, H. G., 5 Elmira St., S.E., Washington 20, D. C.
Peterson, R. A., 405 Belmont Ave., Haddonfield, N. J.
Purcell, R. H., 403 Hudson St., New York 14, N. Y.
Quaranta, S. L., 203 N. Third Ave., Highland Park, N. J.
Rao, V. V. L., Kilpauk P. O., Madras, South India
Roue, J. E., 244 Spring Garden Rd., Halifax, N. S., Canada
Ruth, C. G., 354 Princess Ave., London, Ont., Canada
Schwarzlose, P. F., 212 Electrical Engineering Laboratory, University of Illinois, Urbana, Ill.
Shirling, G. K., 1523 E. 59 St., Kansas City 4, Mo.
Smith, P. L., Naval Research Laboratory, Washington 20, D. C.
Smith, R. L., WRGB, 60 Washington St., Schenectady 5, N. Y.
Soward, R., Box 552, Greenwood, Miss.
Stone, R. P., RCA Laboratories, Princeton, N. J.
Tidball, F. E., 5806—63 Ave., East Riverdale, Md.
Van Alstyne, A. B., Richfield, Wis.

(Continued on page 48A)

The Sherron Cathode Ray Null Detector is available in standard 19" rack mount panel. All electrical characteristics are the same as those of the standard model.

This unit also available with 60-120-1000 cycle oscillator built in.



Model SE 1

SHERRON CATHODE RAY NULL DETECTOR

A Laboratory Precision Instrument Built for Production Application

THE SHERRON CATHODE RAY TUBE NULL DETECTOR is a precision laboratory instrument designed for all A.C. Bridge measurements.

- It is both a high impedance detector and an undistorted, filtered and shielded source of 1000 cycles per second.
- It has a gain of 80 db at an input voltage of 100 micro volts.
- Bridge detector impedance is 1 megohm.
- Use of the Cathode Ray Tube permits the separate positive adjustment of both reactance and resistance with their individual indication on the same Cathode Ray Tube.
- Comparison of frequencies can be obtained by means of Lissajous figures.
- Self protection from overloading is included in this unit. Under any input conditions, the circuit cannot be overloaded or damaged.
- Since head phones are eliminated, this unit can be used in noisy locations by employing the Cathode Ray Tube for visual indication.
- Automatic control of the gain precludes the necessity of resetting while adjusting bridge for balance.

Sherron Electronics
W2XBK

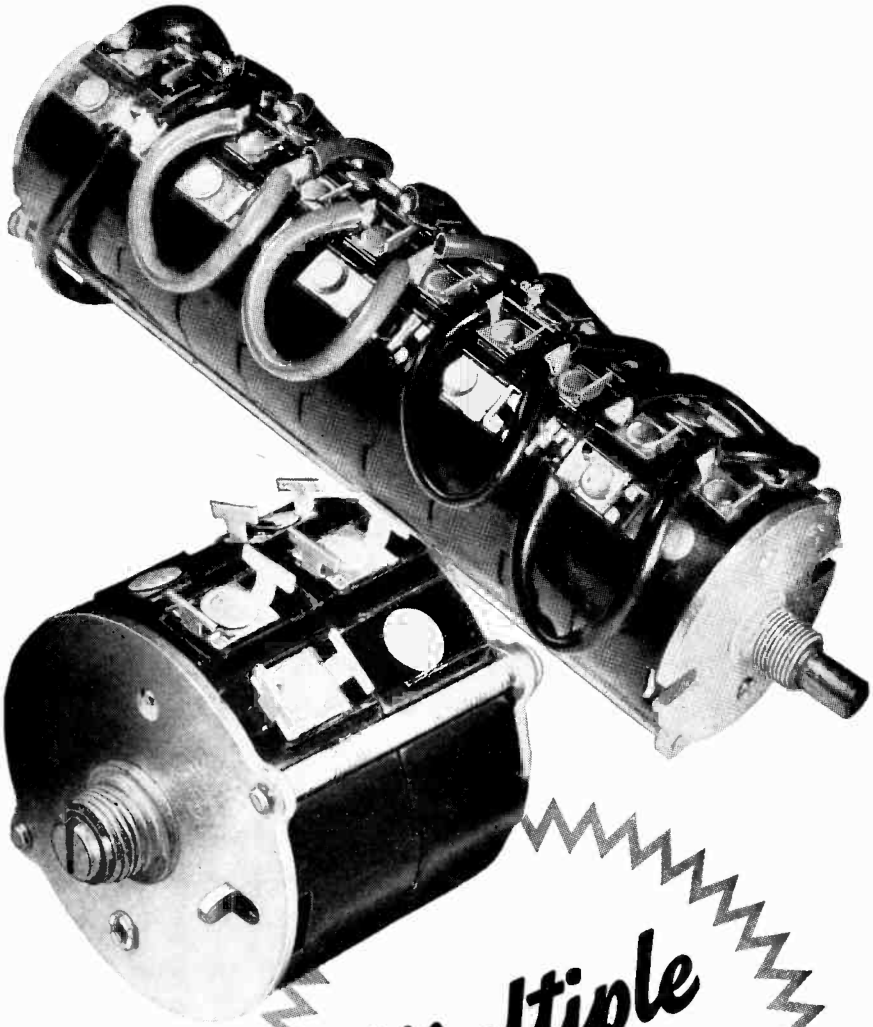
Every precision type Bridge requires a Sherron Precision Null Detector

SHERRON ELECTRONICS COMPANY

Division of Sherron Metallic Corporation

1201 FLUSHING AVENUE, BROOKLYN 6, N. Y.

"Where the Ideal is the Standard, Sherron Units are Standard Equipment"



MEMBERSHIP

(Continued from page 46A)

Van Horn, J. E., 202 N. Piedmont St., Arlington, Va.
Waugh, G. T., General Electric Co., Bldg. 269, Schenectady, N. Y.
Weimer, E. W., 1305—46 St. S.E., Washington 19, D. C.
Wells, M. T., Naval Air Station, Quarters K, Quonset Point, R. I.
Wilby, E. W., RCA Laboratories, 589 E. Illinois St., Chicago 11, Ill.
Wright, O. L., 239 College St., Puente, Calif.

Admission to Member

Baasch, H. C., 105 Harcourt Ave., Bergenfield, N. J.
Berkheimer, R. H., Box 124, RFD 1, Gig Harbor, Wash.
Bluestone, E. S., 83-57—118 St., Kew Gardens 15, L. I., N. Y.
Carpantier, V. J., 102 S. Kilmer St., Dayton 7, Ohio
Cone, J. H., 38 St. Luke's Pl., Montclair, N. J.
Denius, H. R., 48 Merritt Ave., White Plains, N. Y.
Doolittle, H. D., 48 Eighth St., Stamford, Conn.
Etches, E. D., 31 Spruce Court, Toronto 2, Ont., Canada
Frankel, H., 3737 Locust St., Philadelphia 4, Pa.
Gaston, E. E., 1820 Oak Park Ave., Berwyn, Ill.
Godfrey, X. W., 128 Linden Ave., Haddonfield, N. J.
Goldberg, W. P., 309 Westwood Ave., Long Branch, N. J.
Grossmann, J. J., American Telephone and Telegraph Co., Room 1538, Union Commerce Bldg., Cleveland 14, Ohio
Gruol, J. W., 1714 W. Tioga St., Philadelphia 40, Pa.
Halligan, E. P., 7631 N. Eastlake Terrace, Chicago 26, Ill.
Hopkins, C., 20 Chauncy St., Cambridge, Mass.
Jacobs, G., 197 Connecticut Ave., New London, Conn.
King, D. D., 38 DeWolfe St., Cambridge 38, Mass.
Kinney, W. E., 3519 N.W. 13 Ave., Miami 37, Fla.
Lee, H., 611 Church St., Ann Arbor, Mich.
Lindenberg, S., 1576 Unionport Rd., New York 62, N. Y.
Lingren, C. E., 805 Davenport Rd., Toronto 4, Ont., Canada
McLaughlin, W. J., 2367 Burdett Ave., Troy, N. Y.
Paterson, S. G., 155 St. George St., Toronto, Ont., Canada
Patterson, S., 205 Shawnee Rd., Merion Golf Manor, Ardmore, Pa.
Pearlman, L. S., 2 Lewiston Court, Poquonnock Bridge, Conn.
Rollman, R. F., A. B. DuMont Laboratories, Inc., Passaic, N. J.
Spaulding, L. R., 6005 N. Mississippi Ave., Portland 11, Ore.

(Continued on page 54A)

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It takes people to make springs. Ours are specialized, highly trained, long-experienced people—well qualified to give you the finest in spring craftsmanship.

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POSITIONS OPEN

The following positions of interest to I.R.E. members have been reported as open. Apply in writing, addressing reply to company mentioned or to Box No. . . . .

The Institute reserves the right to refuse any announcement without giving a reason for the refusal.

PROCEEDINGS of the I.R.E.
330 West 42nd Street, New York 18, N.Y.

PHYSICISTS

Two Physicists, M.S. or Ph.D. (experience preferred) for long term project in microwave research and development. For details write Box 417.

RADIO INSTRUCTORS

Receiver servicing experience. Degree preferred. $3600 to start; $4200 after 4 months. Work in the heart of the radio industry. Write Raleigh G. Dougherty, c/o New York Technical Institute of New Jersey, 158 Market St., Newark 2, N.J.

PRODUCTION EXECUTIVES

Two executives: Production Manager also Head Production Control Department with several years experience in electronic equipment manufacturing and assembly. Salary $5000 to $8000. Write for interview describing background and experience especially peacetime production responsibilities before the war. Box 418.

EXECUTIVE ELECTRONICS ENGINEER

At once by Connecticut manufacturer who is fast moving into the realms of larger business—must be an engineering school graduate; experienced in radio, electronics, and electricity; must have administrative experience and stature; must have product and production evaluation knowledge; must get along with an energetic, independent organization. Write all details in first letter; salary expected; recent picture. Box No. 415.

FACTORY ENGINEER

We have openings in our Factory Engineering Division for two outstanding men. Experienced background of at least five years engineering work on factory problems relating to receiving tube manufacture required. Engineering degree would be helpful, but primary requirements of the positions are the experience and ability to successfully solve the everyday problems encountered in the manufacture of receiving tubes. Apply by letter to Personnel Department, National Union Radio Corporation, Lansdale, Pa.

ENGINEERS

TELEVISION. Experienced television receiver senior engineer.

RADIO. Experienced home set senior engineer.

Both positions are permanent and offer excellent opportunity and pay. United States Television Manufacturing Corp., 3 West 61st Street, New York 23, N.Y.

WANTED: TOP FLIGHT DESIGN ENGINEER FOR SENIOR ADMINISTRATIVE POST

Must have substantial prior experience in carrying the full responsibility of an engineering department that has a long successful record in producing complete and varied lines of radio transmitters for commercial services, including FM and AM Broadcasting, Point-to-Point Communication, Aviation Marine and Police. The man we are seeking must be a graduate Electrical Engineer with a full, all-embracing theoretical knowledge, combined with extensive practical application. His experience should include first hand knowledge of important recent FM and AM and Microwave developments in the communication field.

Because the man selected for this important post must assume great responsibility, his compensation will consist of a high bracket salary, plus a production bonus incentive. This arrangement will afford him a most unusual opportunity to earn a very substantial income, directly in proportion to his demonstrated ability.

Our company (located in New York City) has been established for many years and enjoys a world-wide reputation for high standard, custom-built communication equipment. Our war record is unexcelled and our post-war expansion program which is already under way, forecasts an important position in the forefront of the communication industry.

This is a job for a man who has reached a ceiling in his present position and must make a change to increase his income, or an assistant chief engineer who has not been permitted the full employment of his capabilities. Write to us, telling enough about your qualifications and past experience to warrant an interview. All communications will be held in strictest confidence. Our organization knows about this advertisement. Address your letter to the attention of the President,

BOX 416
THE INSTITUTE OF RADIO ENGINEERS
330 WEST 42ND STREET, NEW YORK 18, N.Y.

Positions Wanted By Armed Forces Veterans

In order to give a reasonably equal opportunity to all applicants, and to avoid overcrowding of the corresponding column, the following rules have been adopted:

The Institute publishes free of charge notices of positions wanted by I.R.E. members who are now in the Service or have received an honorable discharge within a period of one year. Such notices should not have more than five lines. They may be inserted only after a lapse of one month or more following a previous insertion, and the maximum number of insertions is three per year. The Institute necessarily reserves the right to decline any announcement without assignment of reason.

JUNIOR ENGINEER

BS in EE, broadcast license since 1940, technician. Desire position with station or as assistant in design or manufacture. Age 24. J. M. McClamrock, 7515 E. Burnside St., Portland, Ore.

AAF ELECTRONIC OFFICER

AAF Electronic Officer with good experience in installation and operation of Loran transmitters or receivers. Experienced with all types of control circuits. Box 15W.

ENGINEER

BEE. UHF. Age 22. Some experience in research and design of test equipment. Navy work in radar and communication. Desires research or engineering in electronics near NYC. Available August. Box 16W.

RADIO ENGINEER

BS 1941. Courses at C.C.N.Y., N.Y.U., L.I.U., B'klyn Polytech., Yale, Harvard, and M.I.T. Experience testing, research and teaching. Former Radar countermeasures officer. Desiring position New York area. Box 17W.

ENGINEER

M.I.T. trained radar officer, BS physical chemistry Rutgers 1941, photochemical research, electronic teaching, vacum tube manufacturing experience. Seeks development work electronics or physical chemistry. Box 18W.

RADIO ENGINEER

BS in EE. Three years development electronic equipment and systems. Four years research and development in RF and antenna field both VHF and microwave. Now holding responsible technical position. Available July. Box 19W.

RADAR-COMMUNICATIONS ENGINEER

EE graduate, 25, with Navy officer training at Princeton and M.I.T. in electronics plus duty at NRL. 1½ years experience as radar instructor. First class radio telephone license held. Desires position in June. Box 20W.

ELECTRONICS SALES ENGINEER

3 Years Naval radar project officer, guided missiles and fire control radar. 1 year civilian engineer—radar development. BS physics (radio & electricity) plus

(Continued on page 52A)

THE NEW

S-38's

4 Bands—540 kc. to 32 Mc.

$39.50
ADD 3%
IN
ZONE 2

The Model S-38 meets the demand for a truly competent communications receiver in the low price field. Styled in the post-war Hallicrafters pattern and incorporating many of the features found in more expensive models, the S-38 offers performance and appearance far above anything heretofore available in its class. Four tuning bands, CW pitch control adjustable from the front panel, automatic noise limiter, self-contained PM dynamic speaker and "Airodized" steel grille, all mark the S-38 as the new leader among inexpensive communications receivers.

FEATURES

1. Overall frequency range—540 kilocycles to 32 megacycles in 4 bands.
   Band 1—540 to 1650 kc.
   Band 2—1.65 to 5 Mc.
   Band 3—5 to 14.5 Mc.
   Band 4—13.5 to 32 Mc.
   Adequate overlap is provided at the ends of all bands.
2. Main tuning dial accurately calibrated.
3. Separate electrical band spread dial.
4. Beat frequency oscillator, pitch adjustable from front panel.
5. AM/CW switch. Also turns on automatic volume control in AM position.
6. Standby/receive switch.
7. Automatic noise limiter.
8. Maximum audio output—1.6 watts.
9. Internal PM dynamic speaker mounted in top.
10. Controls arranged for maximum ease of operation.
11. 105-125 volt AC/DC operation. Resistor line cord for 210-250 volt operation available.
12. Speaker/phones switch.

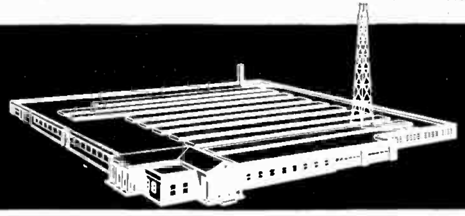
CONTROLS: SPEAKER/PHONES, AM/CW, NOISE LIMITER, TUNING, CW PITCH, BAND SELECTOR, VOLUME, BAND SPREAD, RECEIVE/STANDBY.

EXTERNAL CONNECTIONS: Antenna terminals for doublet or single wire antenna. Ground terminal. Tip jacks for headphones.

PHYSICAL CHARACTERISTICS: Housed in a sturdy steel cabinet. Speaker grille in top is of airodized steel. Chassis cadmium plated.

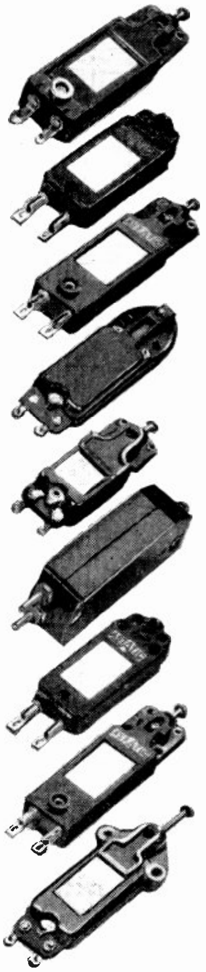
SIX TUBES: 1—12SA7 converter; 1—12SK7 IF amplifier; 1—12SQ7 second detector, AVC, first audio amplifier; 1—12SQ7 beat frequency oscillator, automatic noise limiter; 1—35L6GT second audio amplifier; 1—35Z5GT rectifier.

OPERATING DATA: The Model S-38 is designed to operate on 105-125 volts AC or DC. A special external resistance line cord can be supplied for operation on 210 to 250 volts AC or DC. Power consumption on 117 volts is 29 watts.



hallicrafters RADIO

THE HALLICRAFTERS CO., MANUFACTURERS OF RADIO
AND ELECTRONIC EQUIPMENT, CHICAGO 16, U. S. A.



Positions Wanted

(Continued from page 50A)

engineering subjects, Naval radar schools—M.I.T., Bell Telephone Labs., Bowdoin College. Age 26, dependents. Box 21W.

BEGINNING ENGINEER

Ensign, USNR, being discharged August. BS in EE The Rice Institute. Tau Beta Pi. Age 22. 8 years radio sales and service. Navy radar training. Desire position in southwest U.S. Box 526, Manitou Springs, Colo.

NAVAL ELECTRONICS OFFICER

BEE, age 23, married. First class phone license; broadcast and industrial experience. Desire radio design or broadcast engineer position. Prefer middle west. Available July 1. Box 22W.

ELECTRICAL ENGINEER

BEE, age 24. Instrument research experience. Studied Navy electronic equipment. Commercial operator's license. Prefer east. Box 24W.

SALES ENGINEER

BE Yale 1940, project engineer Naval Research Lab. and Radiation Lab., M.I.T., aeronautical and marine radar, Loran, UHF radio experience. Résumé of experience on request. Box 25W.

ELECTRICAL ENGINEER

BEE, age 27. 1 year civilian development experience, 3½ years Naval officer, specializing in radar, radio maintenance aboard ship. Interested in development, field, or sales position. Consider west coast. Box 23W.

JUNIOR ENGINEER

BS, age 22. Army experience: Development work on radio proximity fuze. Prefer midwest or east. Available April. Box 8W.

POSITION WITH STATION

Age 25, single. Two years Signal Corps. First class license with 3½ years commercial indorsement. Experienced in studio and transmitter maintenance. Also audio and equipment design. Box 9W.

ELECTRICAL ENGINEER

BS in EE, University of California. Age 25, married. 4 years executive experience in research, development, test, and maintenance of electronic and elect-mech devices. Now Naval electronics officer. Available May 1 for manufacturing or consulting firm. Box 10W.

INSTALLATION, TESTING OR CONSTRUCTION

NYU graduate, 1 year experience in telephone office, specification writing and DC machinery test, plus 3 years in field engineering and supervision of construction of Airways radio and navigation facilities. Box 11W.

ELECTRICAL ENGINEER

Electrical engineering plus electronics training as Army officer at Harvard and M.I.T. specializing in radar. Two years experience on ground radar overseas. Supervised maintenance and repair of radar. I. Ginsberg, 20 Gilmer St., Mattapan, Mass.

(Continued on page 54A)

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FROM 10 MICRO AMPERES TO 10,000 AMPERES

Manufacturers of a broad line of SELENIUM Power and Instrument Rectifiers, Photo-Electric Cells and allied scientific products.

Solve your rectification problems with SELENIUM. SELENIUM rectifiers are rapidly becoming standard in industry. Check these outstanding features:

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- √ Immunity to atmospheric changes.
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- √ From 1 volt to 50,000 volts RMS.
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Export Division: Frazer & Hansen, 301 Clay Street, San Francisco 11, Calif.
In Canada: Canadian Line Materials, Ltd., Toronto 13, Canada

46—D

Positions Wanted

(Continued from page 52A)

ENGINEER

Caltech graduate, with development, test, installation, and administrative experience on instrument landing equipment, radio, and radar, consisting of 1 year industry, 2½ years Signal Corps Officer and 10 years practical radio. Box 2W.

ENGINEER

Engineering graduate, age 38, desires permanent position, executive or administrative responsibilities. 11 years commercial engineering experience on radio and television receivers, signal generators, etc. 5 years military experience on airborne radio and radar. Box 3W.

RADIO ENGINEER

Skilled radio engineer located in South Africa desires to join staff of radio factory planned for establishment in that country. Box 5W.

MEMBERSHIP

(Continued from page 48A)

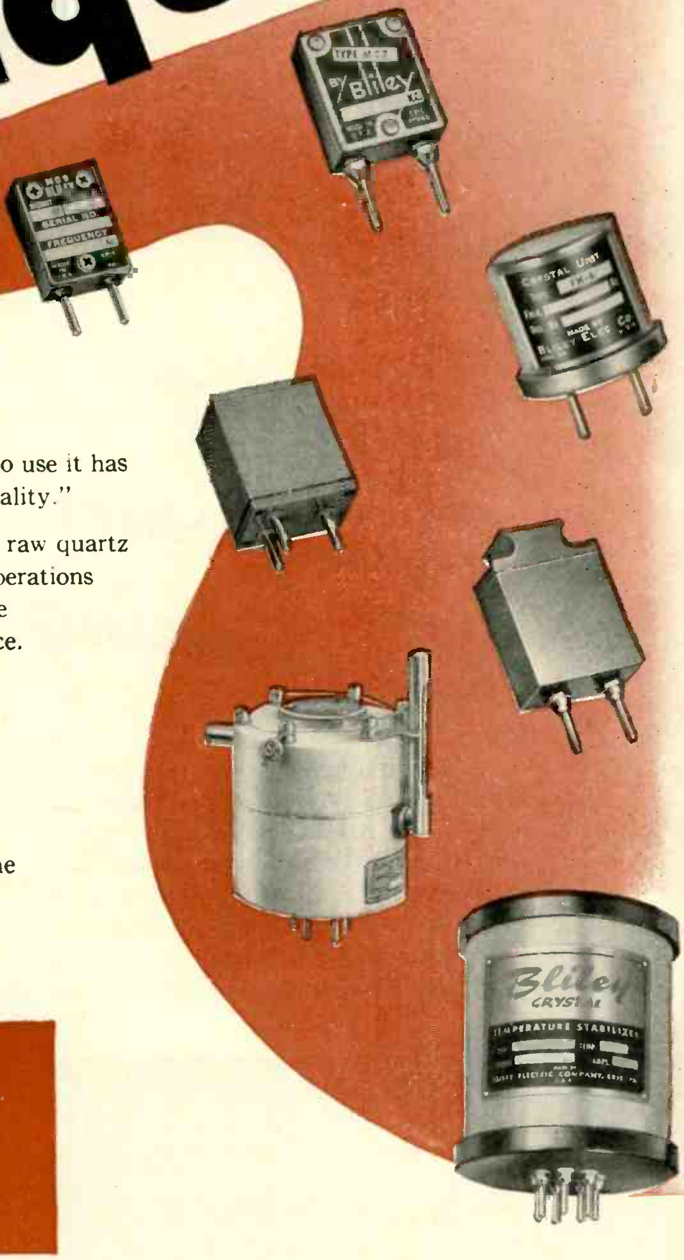
Thomas, A. B., 46, Prospect Rd., Cove, Farnborough, Hants., England
Torvick, E. B., 11938 Exeter Ave., N.E. Seattle 55, Wash.
Waples, P. E., Hazeltine Corp., Little Neck, L. I., N. Y.
Whistler, C. H., 229 Hawthorne St., Brooklyn, N. Y.
Wickre, P. D., 1333 Madison St., N. W., Washington 11, D. C.

Admission to Associate

Abernethy, R. L., 120 Frederick Ave., Babylon, L. I., N. Y.
Akers, R. F., 344 Churchill Rd., West Palm Beach, Fla.
Aldrich, J. A., 65—40 Ave., San Mateo, Calif.
Arteaga, W., 29 W. 82 St., New York 24, N. Y.
Barrett, F. C., Sunnyside, Cheadle, Cheshire, England
Barrett, R. D., 1617 S. Flower St., Los Angles 15, Calif.
Bauser, S. F., Jr., Pan American World Airways, Atlantic Div., 605-B, Miami, Fla.
Bell, E. P., Bell Machine Co., Oshkosh, Wis.
Bellew, H. P., 1736 W. Erie Ave., Philadelphia 40, Pa.
Bonvouloir, F. D., 60 Frederick St., Maple Hill, Newington, Conn.
Borden, T. G., 2200 Cheverly Ave., Cheverly, Hyattsville, Md.
Brodhead, W. M., 126 Newbury St., Boston 16, Mass.
Bulmore, H. R., Simonds Saw and Steel Co., Lockport, N. Y.
Call, S. S., 69 Seymour Ave., Springfield, Mass.
Calnon, D. C., Jr., 2835 N. E. 55 Ave., Portland 13, Ore.

(Continued on page 40A)

Techniquality



Every product that enjoys the full confidence of those who use it has its "priceless ingredient." In Bliley crystals it's "techniquality."

Cutting, grinding, and finishing alone do not transform raw quartz into a sensitive frequency control device. Behind these operations there must be a background of technical skill and creative engineering that is gained only through years of experience.

Bliley crystals have a reputation for "techniquality" that started fifteen years ago. Today, the fact that Bliley crystals are used in practically every phase of radio communications is tacit proof that leading engineers have found it is best to specify Bliley "techniquality" crystals.

Bulletin 27 describes the crystal units engineered for the needs of today. Write for your copy.

Bliley
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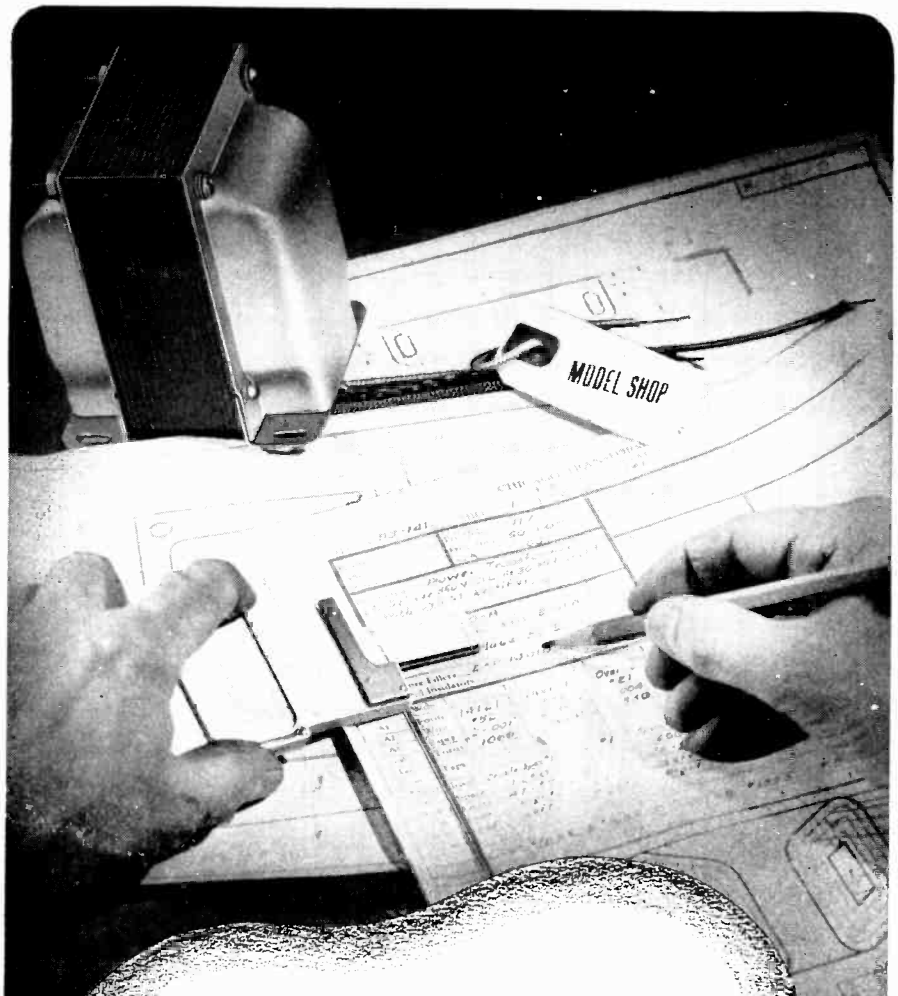


MEMBERSHIP

(Continued from page 54A)

Carlan, L. B., 154 Beach 68 St., Arverne, L. I., N. Y.
Carlson, G., 306 N. 63 Ave., W., Duluth, Minn.
Carman, E. B., 68 Homestead Ave., Bridgeport 5, Conn.
Carson, R. S., 415 E. Washington Blvd., Fort Wayne 2, Ind.
Celnar, P. J., 1556 Myrtle Ave., Columbus 3, Ohio
Chernoff, B., RFD 3, Newburgh, N.Y.
Chiang, F. Y. K., Electrical Dept., Sung Sing
Cotton Mill 9, 140 Macao Rd., Shanghai, China
Chiles, W. R., 2829 S. W., 13 St., Miami 35, Fla.
Cobin, F., 158 E. Seventh St., New York 9, N. Y.
Cole, L. S., 696 E. Fourth North St., Logan, Utah
Corby, L. A., Hefco Agencies, 53 Yonge St., Toronto, Ont., Canada
Cox, L. E., 308 S. Jefferson Ave., Springfield, Mo.
Crosby, H. K., 941 Hillside Ave., Norfolk 3, Va.
Curtice, J. D., Park Lee Apartments, 1630 Park Road, N. W., Washington 10, D. C.
Dean, C. M., 16 Oak Grove, Manchester, Conn.
Decker, A. P., KFFA, Helena, Ark.
Desmond, W. F., Suite 722, 38 S. Dearborn St., Chicago 3, Ill.
de Wolfe, G. C., 117-A North Park Ave., Montebello, Calif.
Dorratcague, P. E., 18 Oak Grove Dr., Baltimore 20, Md.
Eckert, J. A., Jr., 5514 Ruthelen St., Los Angeles 37, Calif.
Eichert, E. S., Moore School of Electrical Engineering, 33 and Walnut Sts., Philadelphia 4, Pa.
Fahsing, W. F., 230 E. 25 St., New York 10, N. Y.
Feaker, R. L., 3418 Highland, Kansas City 3, Mo.
Figlia, J. R., Fairchild Camera and Instrument Corp., 88-06 Van Wyck Blvd., Jamaica 1, L. I., N. Y.
Fortin, R. A., CBV, Charlesbourg Village, Que., Canada
Fowler, C. A., Box 32, East Norwich, L. I., N. Y.
Fox, C. A., 1712 W. 70 St., Los Angeles 44, Calif.
Frazier, R. L., Hq., Air Matériel Command, TSEWS All Weather Flying Division, Wright Field, Ohio
Futchik, A. J., 735 Lime Ave., Long Beach 2, Calif.
Garber, T., 290 Massachusetts Ave., Cambridge 39, Mass.
Golby, A. R., 231 Edward St., London, Ont., Canada
Graf, V. V., Seismograph Service Corp., Box 1590 Tulsa 1, Okla.
Graham, H. E., 2471 Queen St. E., Toronto 8, Ont., Canada

(Continued on page 58A)

"Better tube life . . . less production shrinkage" with ZIRMET, says Raytheon

Interesting new development by Raytheon is a mercury vapor rectifier with Zirmet acting in the role of a built-in vacuum pump.

"Zirmet" is Foote Mineral Company's 99.9+% pure ductile zirconium.

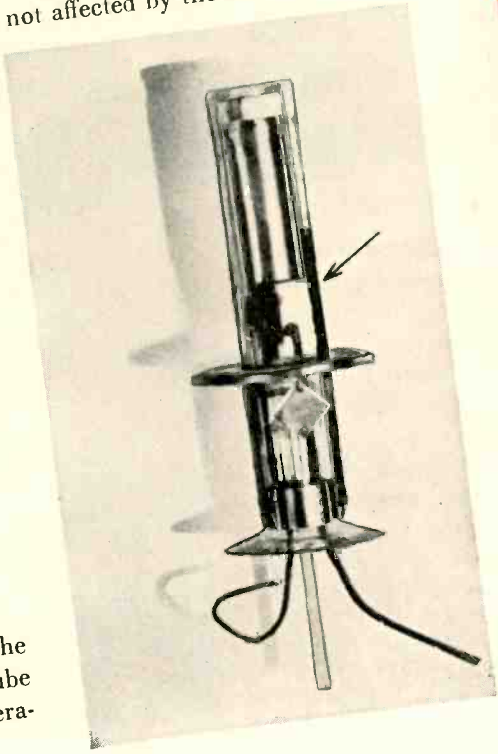
Small Strip of Metal Effective

The Raytheon rectifier requires only a ribbon of Zirmet 1/8" wide x 1" long x .003" thick for its job as a getter.

The Zirmet ribbon is welded to the cathode shield support. In normal tube operation the Zirmet reaches a temperature of about 650°C.

Not Affected by Mercury Vapor

Raytheon has this to say about Zirmet —"The use of Zirmet has resulted in better tube life and less production shrinkage." Zirmet, unlike some other getters, is not affected by the mercury vapor.



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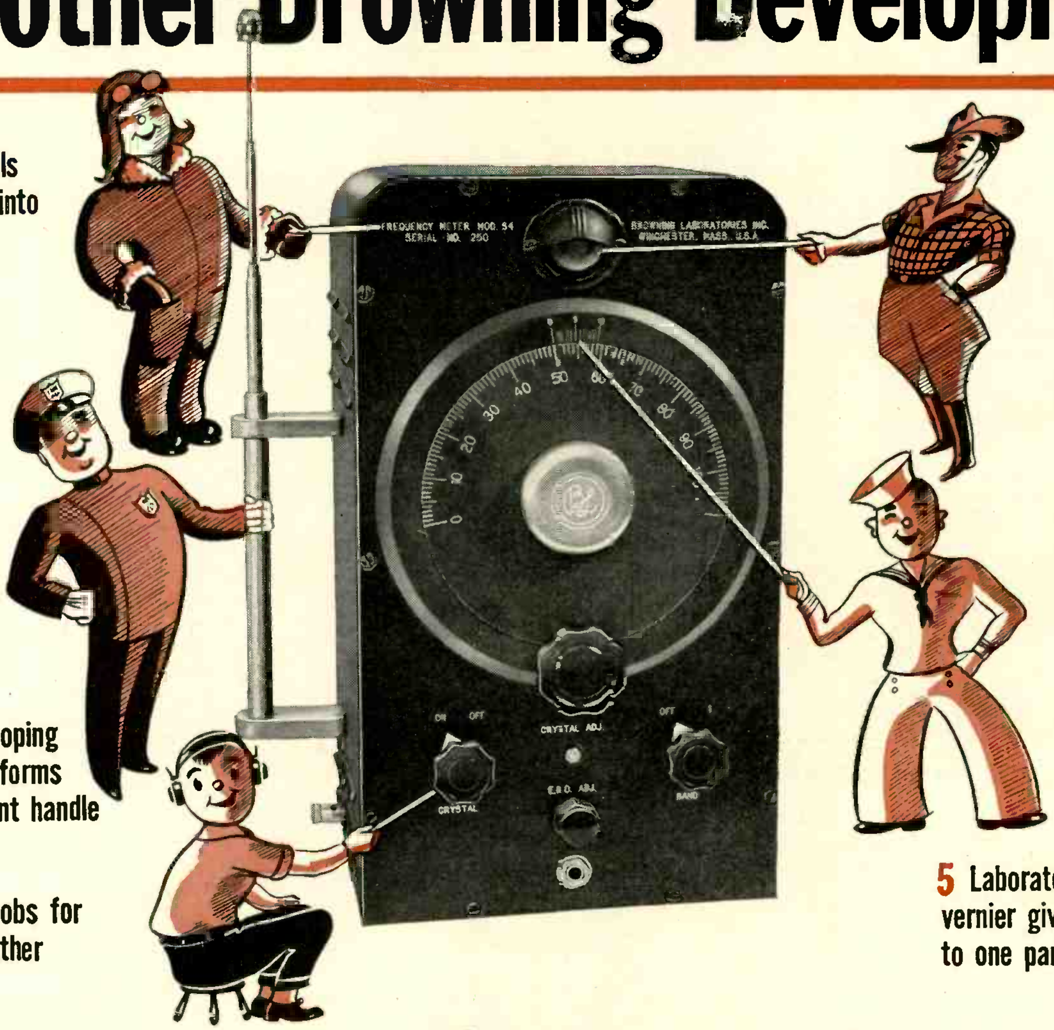
MEMBERSHIP

(Continued from page 56A)

Gross, F. A., 57 Rockland St., Swampscott, Mass.
Gross, V., 1009 Lincoln Pl., Brooklyn 13, N. Y.
Gruenfelder, R. J., 111 S. Third St., New Hyde Park, N. Y.
Hale, C. F., 3812 Bernice Dr., San Diego 7, Calif.
Hargrave, E. T., 501 W. 142 St., New York 31, N. Y.
Hart, W. E., 616 Mt. Zoar Street, Elmira, N. Y.
Heffernan, C. S., Hefco Agencies, 53 Yonge St., Toronto, Ont., Canada
Henning, E. S., TSERR-2D3C, Hq., ATSC, Wright Field, Dayton, Ohio
Heros, R., 144 W. 82 St., New York 24, N. Y.
Hickman, J. S., 216 Ave. C., Redondo Beach, Calif.
Holden, M., 18 E. 199 St., Bronx, N. Y.
Horowitz, S., 1673—64 St., Brooklyn N. Y.
Hyde, J. E., Jr., 248 Sheridan Ave., S., Minneapolis, Minn.
Jacobsen, S. J., 4465 Winona, San Diego 5, Calif.
Jacobson, N., 1697 Andrews Ave., Bronx, N. Y.
Jeffers, L. B., Sr., 1504 ½ Ash Ave., Independence, Mo.
Jones, R. M., Jr., 1601—13 Court, N., Birmingham 4, Ala.
Jordan, L. V., 1710 W. Webster, Houston, Tex.
Keast, A. K., 844 Waller St., San Francisco, Calif.
Kerver, N. E., 189-10—37 Ave., Flushing, L. I., N. Y.
Kups, E. F., 552 S. 19 St., Newark 3, N. J.
Lang, H. J., Box 1663, Santa Fe, N. M.
Mi, L., N.R.C. Office of China, 111 Broadway, New York 6, N. Y.
Lewis, C. W., Jr., 111 Union St., Schenectady 5, N. Y.
Liddiard, G. E., 7626 Fay Ave., La Jolla, Calif.
Lindley, L. E., Sylvania Electric Products, Inc., Emporium, Pa.
Lipman, N., 611 Bond St., Asbury Park, N. J.
Maisel, W. A., 6516 N. E. 22 Ave., Portland 11, Ore.
Marshall, R. T., 211 Hazard St., Houston 6, Tex.
McCoy, E. W., Jr., 56 Elliott Ave., Yonkers 5, N. Y.
McKay, H. B., 1379—35 Ave., San Francisco 22, Calif.
Michaels, H. M., 1455 Fulton Ave., Bronx 56, N. Y.
Miller, O. M., Vandalia Rd. RFD 5, Des Moines 17, Iowa
Milton, O., Westinghouse Electric Corp., X-Ray Division, 233 S. St. Francis St., Wichita, Kan.
Minor, W. H., 510 S. Franklin St., Muncie, Ind.
Monell, M. B., 1722 Asbury Dr., Pasadena 7, Calif.

(Continued on page 60A)

Another Browning Development



1 All labels engraved into panel

2 Telescoping antenna forms convenient handle

3 Big knobs for cold weather handling

4 Visual determination of zero beat by cathode ray indicator

5 Laboratory-type dial with vernier gives readability to one part in one thousand

6 New non-jamming vernier drive for fine adjustment

7 Uses WWV as primary standard

8 Rugged steel cabinet and ⅛" aluminum panel

9 Audio output for audibly detecting beats

10 110-115 AC-DC operation — checks AM or FM

BROWNING'S Model S-4 Frequency Meter was designed especially for marine, police, aircraft, fire department, and other special service radio operators, who must be certain that transmitters are on frequency.

Completely new, it incorporates all the features that supervisors of emergency radio systems have requested — plus many new refinements perfected during our war experience in designing high-precision radar test equipment.

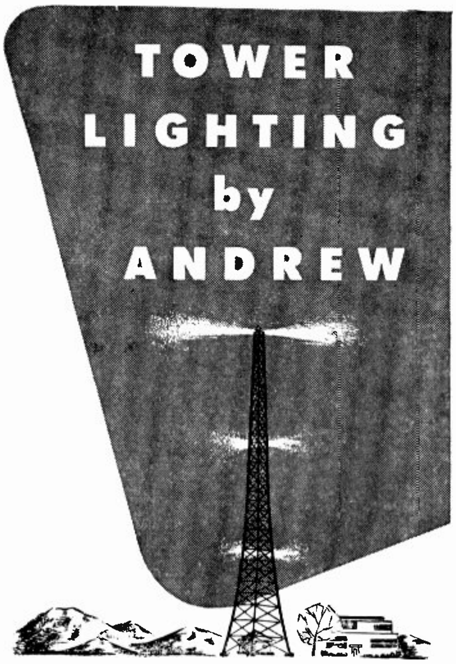
For example, we have included a vernier on the new laboratory-type scale, permitting reading accuracy to one part in one thousand. A telescoping antenna has been added to the side of the case. When telescoped, it forms a convenient carrying handle. Big, easy-to-hold knobs let you operate the meter with gloves on, in cold weather.

The highest degree of stability has been built into the Model S-4 by the use of improved circuits and voltage regulation within the unit. FCC requirements of plus or minus .00025% accuracy are exceeded by the crystal-controlled BROWNING Frequency Meter. Using 110-115 volt A.C. or D.C. current, it checks both AM and FM equipment.

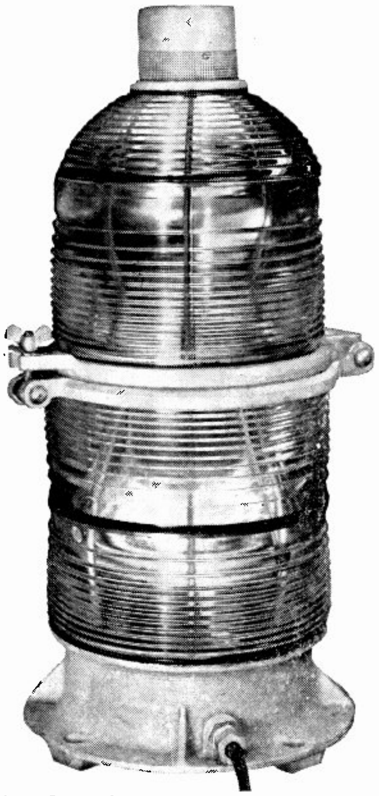
The S-4 is custom built and hand calibrated for testing frequencies in any five bands from 1.5 to 100 mc., according to the user's requirements. For additional technical data and other information, address BROWNING LABORATORIES, Inc., Winchester, Mass.

BROWNING

LABORATORIES, INCORPORATED
WINCHESTER, MASSACHUSETTS

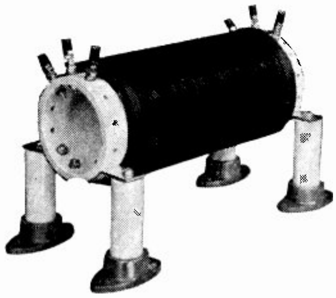


TOWER LIGHTING by ANDREW



CODE BEACON FOR RADIO TOWERS

A 300 MM code beacon designed and built by ANDREW for lighting radio towers as aviation hazards. Required by the CAA on radio towers of 150 feet or greater in height. Two 500-watt prefocus lamps provide an intense light which passes through red pyrex glass filters and is radiated in a circular, horizontal beam by cylindrical fresnel lenses. Metal parts are made of light-weight cast aluminum, with hardware of corrosion-resistant bronze.

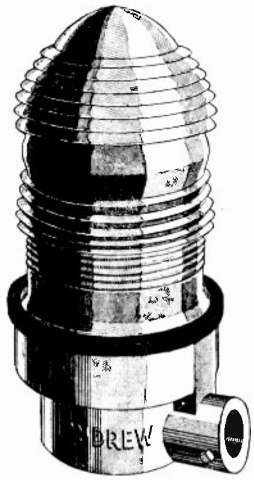


LIGHTING FILTER. The ANDREW Model 1803 lighting filter serves to connect the 60-cycle lighting voltage across the base insulator of a series excited tower without detuning the tower. Three windings provide for operation of code beacon and obstruction lights. Mica insulated by-pass condensers of ample current rating included. Also offered in weatherproof steel housing.

Pioneer Specialists in the Manufacture of a Complete Line of Antenna Equipment

ANDREW CO.

363 EAST 75th STREET
CHICAGO 19, ILLINOIS



OBSTRUCTION LIGHT. Type 661 is a 100-watt unit fitted with a red fresnel lens to concentrate the light in a nearly horizontal direction. Used in pairs at 1/3 and 2/3 levels on radio towers for aircraft warning.

BURNOUT INDICATORS. Highly damped meter with special wattmeter scale indicates when code beacons or obstruction lights need re-lamping.

FLASHERS. Designed to flash 300 MM code beacons at rate of 40 cycles per minute, as prescribed by government regulations. Flashers have 25-ampere contacts and condensers for radio interference elimination. Use K-10347 for one or two beacons; use K-10348 to maintain constant 2000-watt load with three beacons.

TIME SWITCHES. Switch tower lights on at sunset and off at sunrise. Special astronomic dial follows seasonal variations in sunset and sunrise time. Photo-electric models also available.

LAMPS. A complete stock of lamps for code beacons and obstruction lights is carried for the convenience of users. Available in a wide variety of filament voltages.

MEMBERSHIP

(Continued from page 58A)

Motley, L. C., 228 Clement Ave., Danville, Va.
Nelson, J. A., Airborne Instruments Laboratory, Inc., 160 Old Country Rd., Mineola, L. I., N. Y.
Nelson, P. H., 18 Rahway Rd., Millburn, N. J.
Newman, J. E., WDBJ, Roanoke 2, Va.
Nifong, H. A., KAVE, Carlsbad, N. M.
O'Neil, D. H. C., 5740 Bartmer Ave., St. Louis, Mo.
Pecar, A. J., 11824 Payton Ave., Detroit 24, Mich.
Perkins, R. W., 606 E. 80 St., Chicago 19, Ill.
Pettersen, G. A. A., Box 30, 27 Ross St., Flin Flon, Manit., Canada
Phelps, W., 1710 Richmond Ave., Houston 6, Tex.
Phillips, F. S., 809 W. 32 St., Houston 8, Tex.
Plog, K., American Telephone and Telegraph Co., 4100 Bryan St., Dallas 1, Tex.
Poloway, A. A., 111 Luxton Ave., Winnipeg, Manit., Canada
Pritchard, D. A., 2496 Derbyshire Rd., Cleveland Heights 6, Ohio
Reiss, N. D., 7629 E. Jefferson Ave., Detroit 14, Mich.
Richards, R. R., 2350 Creston Ave., Bronx, N. Y.
Ritter, H. C., 5620 N. E. Cleveland Ave., Portland 11, Ore.
Robinson, J. C., 1422 San Jacinto St., Houston 2, Tex.
Rosenberg, S. L., 1312 Stratford Ave., New York 59, N. Y.
Russ, F. J., 557 Lebaum St., S. E., Washington 20, D. C.
Santino, L., 194 Gelston Ave., Brooklyn 9, N. Y.
Schure, A., 41-15—46 St., Sunnyside, Long Island City 4, L. I., N. Y.
Schwarz, H., Standard Electrica Sa., Box 430, Rio de Janeiro, Brazil
Schwenk, C. C., 3810 Gwynn Oak Ave., Baltimore 7, Md.
Seiler, N. B., 3518 W. 60 St., Chicago 29, Ill.
Sewell, C., Jr., Box 1663, Santa Fe, N. M.
Shabeck, J. C. L., Jr., 101 Crescent St., Waltham 54, Mass.
Sherman, C. M., 92 Western Ave., Morristown, N. J.
Shoulders, H. D., 150 Dakota St., San Francisco 7, Calif.
Shulman, I., 1117 Manor Ave., Bronx 59, N. Y.
Siegel, E. J., 1350 N. 46 St., Milwaukee 8, Wis.
Silbar, J. I., 31-14—103 St., Corona, L. I., N. Y.
Slimm, A. W., 2853 N., Palethorp St., Philadelphia 33, Pa.
Smith, L. A., 26 Chauncy St., Cambridge 38, Mass.
Stoll, V. B., 237 Elm St., Lancaster, Pa.
Taintor, H. G., Jr., 94 Locust St., Winthrop 52, Mass.

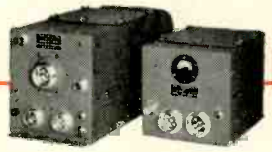
(Continued on page 62A)

your **Signpost** in the sky

For the private pilot who wants the last word in complete air-ground radio, ARC now offers equipment built to exacting Army-Navy standards. Featuring designs tested through millions of hours of wartime operation, the ARC Type 11 Aircraft Communication System provides top quality performance under conditions of vibration, moisture, changes in altitude and temperature, and shocks from rough landings.

The Type 11 System combines a wide band (190 to 550 KC) LF Range Receiver and a VHF Transmitter with provision for 5-channel operation at the turn of a switch. The small separate control unit is located for convenience of operation and the major units remotely mounted. This avoids disturbance of normal weight and balance of the airplane and usually permits a short antenna lead-in. The complete antenna system consists of a single vertical rod 22 inches long and is furnished with the Type 11 System.

This compact ARC equipment is based on more than 18 years of design and development in the field of airborne radio and is a *quality* instrument for the operator who requires the basic essentials in aircraft communication and navigation facilities. Remember, when selecting the radio for your airplane, nothing but the best is good enough—specify ARC. For descriptive information and prices, write Aircraft Radio Corporation, Boonton, New Jersey.



ARC ADVANTAGES

Light Weight — Less than 15 pounds for the entire Type 11 System installed.

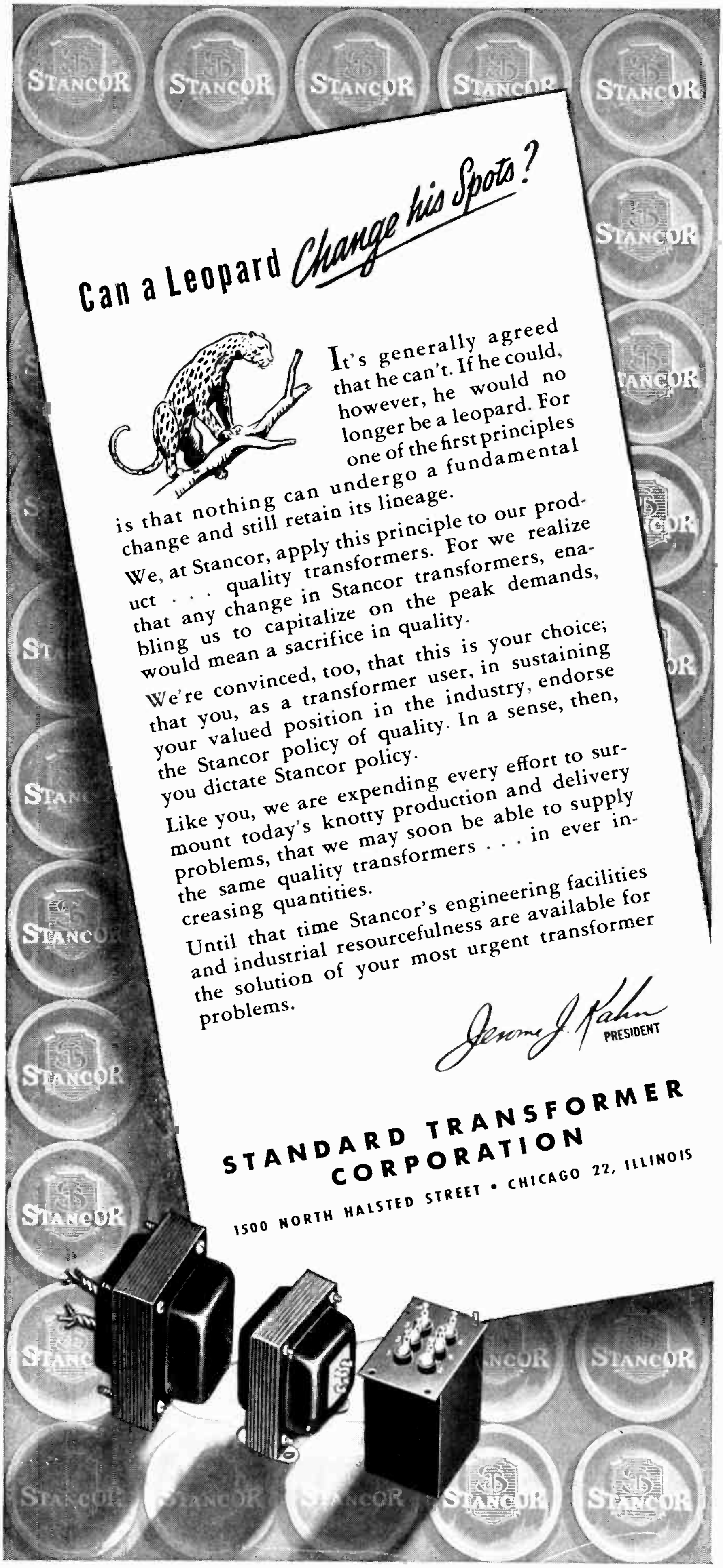
Reliable Reception — Unusual sensitivity and selectivity plus rugged construction. Noise-limiting circuitry insures clarity of reception and makes shielding unnecessary in some airplanes.

VHF Transmission—Crystal-controlled on 2 present channels, with provision for 5-channel operation to cover additional frequencies when allocated.

A Complete Installation — The Type 11 System is available complete with antenna, crystals, tubes, cables, microphone and headset — no extras to buy.

AVAILABLE FOR DELIVERY JULY 1, 1946

AIRCRAFT RADIO CORPORATION
BOONTON, NEW JERSEY



MEMBERSHIP

(Continued from page 60A)

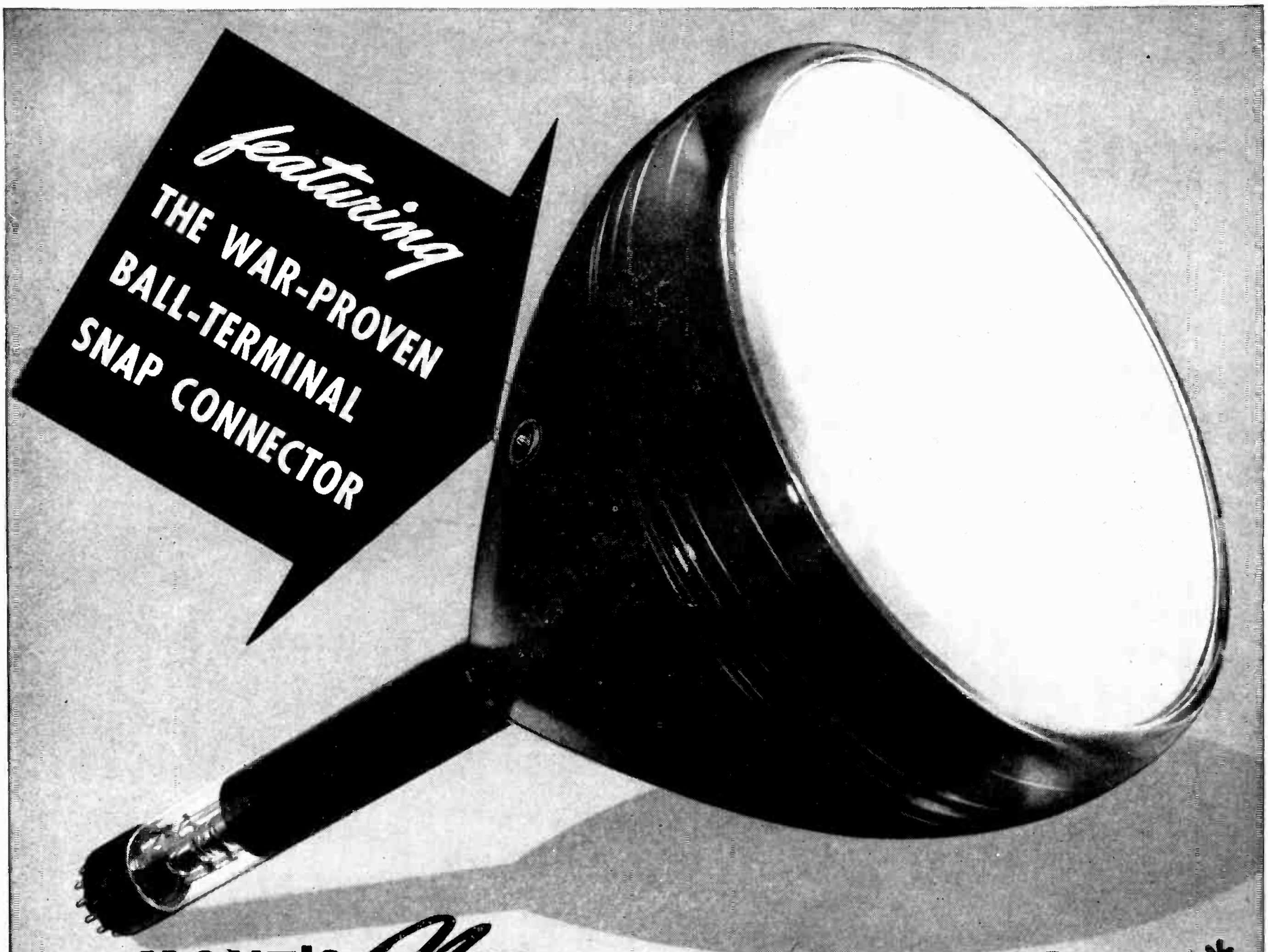
Toye, J. M., 168 Trenton Ave., Montreal 16, Que., Canada
Vernon, H., 845 Downing St., Winnipeg, Manit., Canada
Vitrogan, D., 312 E. 21 St., Brooklyn 26, N. Y.
Walker, R. M., 75 Brent St., Dorchester 24, Mass.
Walters, A. W., 149 Danbury St., S. W., Washington, D. C.
Walton, G. A., Walco Radio Co., 8624 Gravois Ave., Affton 23, Mo.
Way, A. H., Y.M.C.A., Stamford, Conn.
Weaver, J. J., 304 N. E., 99 St., Miami Shores 38, Fla.
Weingarten, J., 2003 Commonwealth Ave., Boston 35, Mass.
Wheeler, R. B., Airborne Instrument Laboratory, Inc., 160 Old Country Rd., Mineola, L. I., N. Y.
Wilcoxon, L., 2921 Simpson St., Evanston, Ill.
Wilson, J. W., 12237 Morrison St., North Hollywood, Calif.
Wishneski, F. G., 146 Alexander St., Newark 6, N. J.
Witkin, E., State Hospital, Norristown, Pa.
Wright, T. A., 3244 Valley Dr., Park Fairfax, Alexandria, Va.
Wyman, J. E., Box 331, Brentwood, L. I. N. Y.
Yerkes, H. W., Neshaminy, Pa.
Younson, E. J., 120 Bede Burn Rd., Jarrow, County Durham, England
Zamorano, A., 144 W. 82 St., New York 24, N. Y.
Zanetti, C. E., Calle 25, No. 718, Vedado, Habana, Cuba
Zeidell, M., 2118—46 Ave., San Francisco, Calif.

Westinghouse Resumes Fellowships

Westinghouse Electric Corporation has announced resumption of fellowships to young scientists for work on pure scientific research of their own choosing. L. W. Chubb (M'21–F-'40), director of Westinghouse Research Laboratories, said applications have been forwarded to universities and government research laboratories to select three outstanding young men for a year's work at the Westinghouse Laboratories. The board of review for selecting appointees will include Dr. Chubb, and C. R. Hanna (M'28–SM'43), J. A. Hutcheson (M'28–SM'43), and Joseph Slepian (SM'45–F'45), associate directors. The group will also serve as an administrative staff for supervising and following work of the appointees.

Under the plan, young scientists having training equivalent to that represented by a doctor's degree from a recognized university are chosen to perform research which they themselves outline and initiate. The fellowship has a value of $3300 a year, and the

(Continued on page 68A)



DU MONT'S *New* TELETRON*
10EP4

A new 10-inch magnetic focus and deflection cathode-ray tube suitable for television applications requiring excellent performance at low price. In addition to the ball-terminal snap connector, other outstanding features include ion-trap gun to insure long screen life, new high-efficiency screen, essentially flat face, external conductive coating which can be used for power supply filter capacitor, and new standard duodecal television base.

NOW AVAILABLE IN PRODUCTION QUANTITIES!

TYPICAL OPERATION

Heater voltage	6.3 v.
Anode voltage (Eb)	8,000 v.
Second grid voltage (Ec2)	250 v.
Negative grid voltage (Ec1) for beam cutoff	45 v. (+25, —20 v.)
Grid drive (at Ib-200 μa.)	38 v. max.

*Registered trade-mark

DUMONT *Precision Electronics & Television*

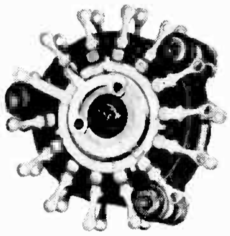
ALLEN B. DUMONT LABORATORIES, INC., PASSAIC, NEW JERSEY • CABLE ADDRESS: ALBEEDU, PASSAIC, N. J., U. S. A.

YOU CAN NOW GET THESE DAILY ESSENTIALS

• • •

INSTRUMENT & TESTER SWITCHES

12-14 and 20 position. Shorting; non-shorting 1-6 decks.


(SS-14-2)

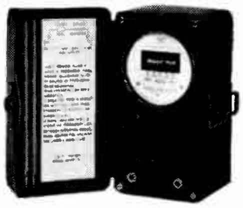
OPERATING TEMPERATURE TESTERS

Automatically compensated, typical range for ovens, 0-650°F.


(32-JPI)

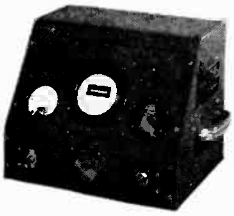
400 CYCLE PORTABLES

Accuracy to ±0.3%; pocket size metal case; other ranges.


(33-FP9-400 cy.)

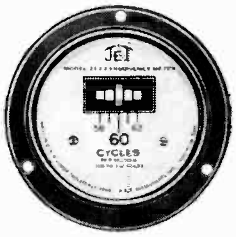
VACUUM-TUBE FREQUENCY METERS

Accuracy, ±0.25%; six specific bands, to 3600 cps. No drift.


(39-VTF)

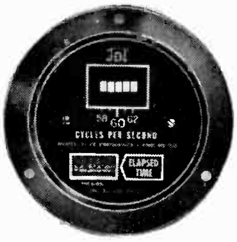
MOST COMPACT FREQUENCY METERS

Matches standard 2½" panel instruments. 60, 120 cps.


(21-FX-60 cy.)

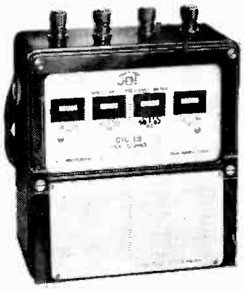
ELAPSED TIME—FREQUENCY METERS

3¼" mounting; encourages periodic servicing and tube-life checking.


(31-FE)

MULTIPLE RANGE PORTABLES

Standard—4 frequency groups at 3 voltages. Many special order variations.


(60-FP)

POTENTIOMETER-PYROMETERS

Measures and follows temperatures continuously after initial balancing.


(70-PO)

. . . many of these, and others from the J-B-T line, are now stocked by leading jobbers.

J-B-T INSTRUMENTS, INC.

423 CHAPEL STREET • NEW HAVEN 8, CONNECTICUT

WIRE & RIBBON for VACUUM TUBE FILAMENTS & GRIDS

✓ Many sizes and alloys for a range of applications such as miniature tubes, hearing aid tubes, low-current-drain battery tubes, receiving tubes . . .

✓ Melted and worked to assure maximum uniformity and strength. WIRES drawn to .0004" diameter; RIBBON rolled to .0001" thickness . . .

✓ Wollaston Process Wire drawn as small as .000010"; made to your specifications for diameter and resistance.

✓ SPECIAL ALLOYS made to meet individual requirements. Write for list of stock alloys.

SIGMUND COHN & CO.

44 GOLD ST. NEW YORK

SINCE 1901

SOUND EQUIPMENT—*precisionized*—**mechanically and electronically**—*for finer performance*

Solidly Built

Unit 524
Transcription
Turntable

To keep the original sound alive!

Today, the human ear should not be able to distinguish a recorded program from an original 'live' studio performance.

Why? Because all tell-tale rumble, noise and 'WOWS' have been eliminated from transcription turntable performance.

How? By the advanced design and solid construction of the *new* Unit 524 Fairchild Transcription Turntable.

We've removed its attractive access panel so that you can study it carefully. Let's start with its construction: The synchronous motor and drive are spring-mounted and precision-aligned in a single heavy casting at the bottom of the cabinet to reduce rumble. The hollow vertical drive shaft is equipped with mechanical filters and a special rubber coupling to reduce the transmission of vibration. And the turntable, with its sturdy shaft, is mounted in a heavily-webbed aluminum panel at the top of the cabinet to further reduce vertical vibration.

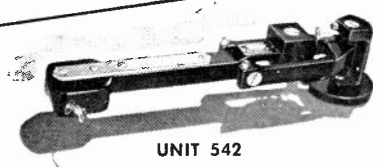
What about 'WOW'? That's reduced to a minimum at either 33.3 or 78 rpm by the famed Fairchild direct-from-the-center, two-speed drive. Evenness of speed is assured by a carefully calculated loading of the drive mechanism that keeps the motor pulling constantly, by precision control of all alignments that might cause intermittent grab and release.

The Unit 524 Fairchild Transcription Turntable is of broadcast height. It is available with or without the Unit 542 Fairchild Lateral Dynamic Pickup, illustrated below. Arrange to hear it. Listen to it critically. Then let it keep your original sound alive! Address: 88-06 Van Wyck Boulevard, Jamaica 1, New York.

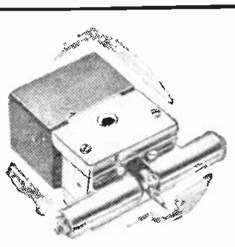
SOUND EQUIPMENT

FCI *Fairchild* **CAMERA AND INSTRUMENT CORPORATION**

FOR IMPROVED PERFORMANCE



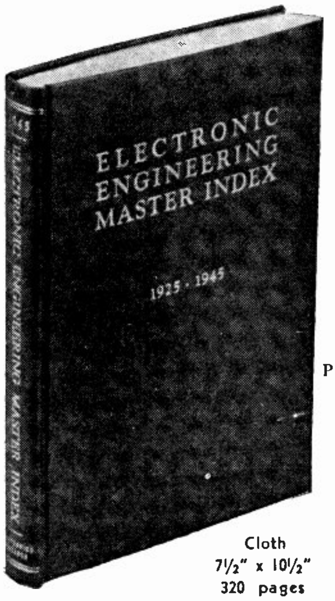
UNIT 542
LATERAL DYNAMIC PICKUP

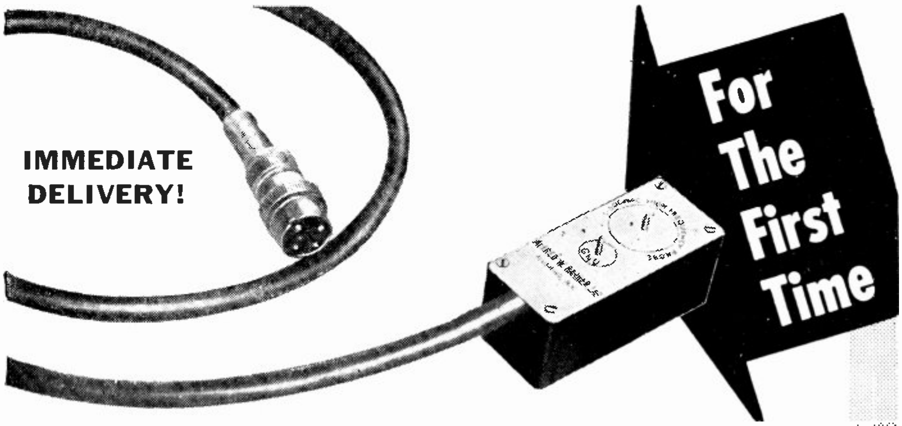


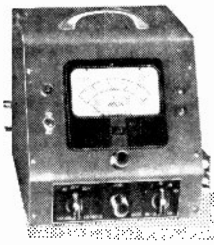
UNIT 541
MAGNETIC CUTTERHEAD

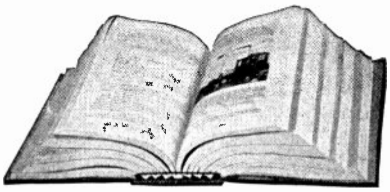
Earlier FAIRCHILD portable models and many other types of recorder-playbacks will give vastly improved performance if equipped with an adapter and an improved Fairchild Pickup and Cutterhead.

Write for complete information.

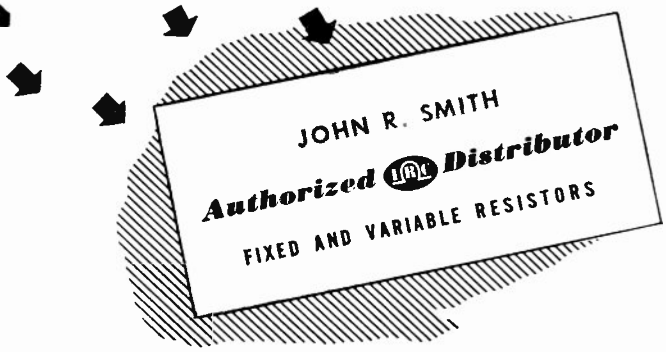

ELECTRONIC ENGINEERING MASTER INDEX
1925 - 1945


For The First Time





THE MAN TO KNOW...



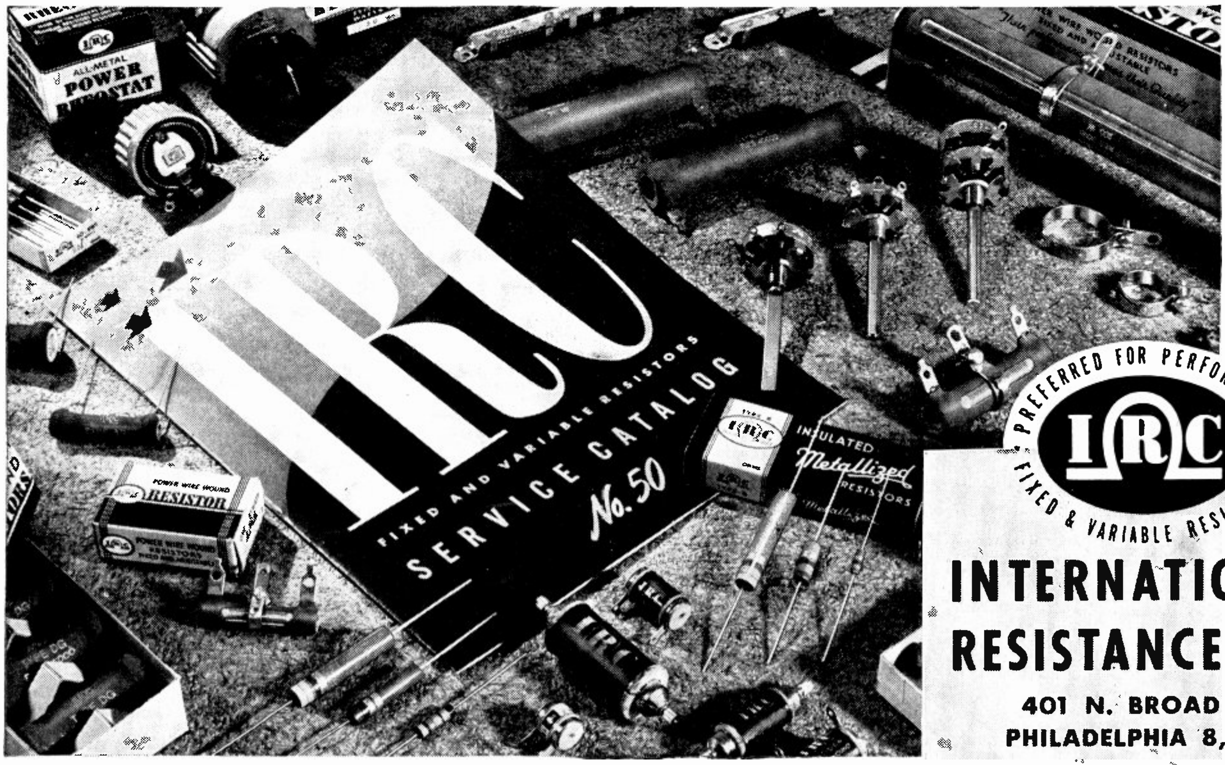
... when you need resistors in a hurry!!!

IRC distributors always have been valuable supplementary sources of supply to manufacturers of electronic and industrial equipment. During the war, they established an unusual record of service to manufacturers. IRC's more than 300 Authorized Distributors have proved themselves to be of the highest caliber, with exceptional organizations and facilities.

Under the newly-announced IRC Industrial Service Plan, these men are better prepared than ever before to give industrial users of resistance units prompt, intelligent and complete service on all IRC standard products, listed in IRC Catalog #50. They are rapidly gearing to maintain adequate stocks of the most widely-used IRC resistors and their sales forces are conversant with electronic requirements.

When you need resistors in moderate quantities for experimental work, pre-production models, pilot runs, small production runs, and for service and maintenance—it will pay you to call upon your local IRC distributor. We shall be glad to furnish his name upon request.

Write to Dept. 11-E for IRC Catalog #50 and names of local IRC Distributors.



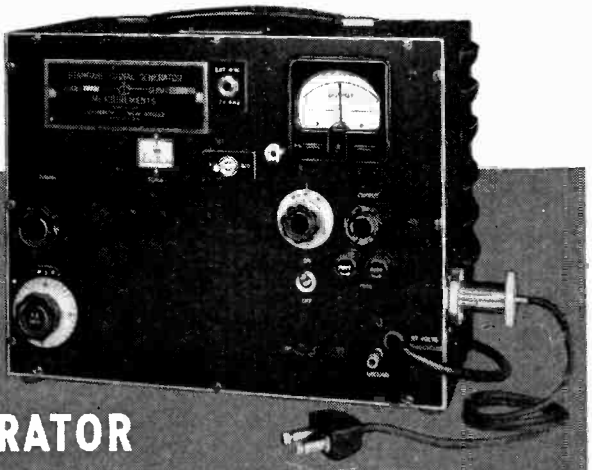
PREFERRED FOR PERFORMANCE
IRC
FIXED & VARIABLE RESISTORS

INTERNATIONAL RESISTANCE CO.

401 N. BROAD ST.
PHILADELPHIA 8, PA.

Canadian Licensee:
International Resistance Co., Ltd., Toronto

FOR BETTER-THAN-STANDARD QUALITY... *Standardize on IRC*



Westinghouse Resumes Fellowships

(Continued from page 62A)

men may be reappointed for a second year. Considered important are investigations of the fundamentals of ferromagnetism and the properties of semiconductors; and problems in the fields of nuclear physics, conduction of electricity in gases, dielectrics, thermionics, applied mechanics, and chemical physics are also appropriate.

The discovery of photofission—the splitting of uranium atoms by high-energy gamma rays with a commensurate release of large amounts of energy—was made in 1940 by three Fellows appointed in 1938. W. E. Shoupp (SM'45), one of the codiscoverers, is now manager of the Laboratories' electronics department and has been active during the war in the development of radar devices and countermeasures. Another direct outcome of fellowship projects is the development of the transmit-receive box, a superspeed electronic switch used in radar equipment, one of whose coinventors is Sidney Krasik (M'43), presently electronics department section engineer. Sidney Siegel (S'43–A'44) magnetics department section engineer, has advanced the theories of magnetism and the knowledge of magnetic materials.

Industry Opens New Fields For Electron Tubes

After a quarter-century of service in the entertainment and communications field, the electron tube is now ready to realize its full, vast potentialities in peaceful commerce and industry, according to L. W. Teegarden vice-president in charge of the tube department of the Radio Corporation of America. The year ahead should be marked by a substantial start toward this realization. Eventually, the production of tubes for nonradio purposes will exceed that for radio applications.

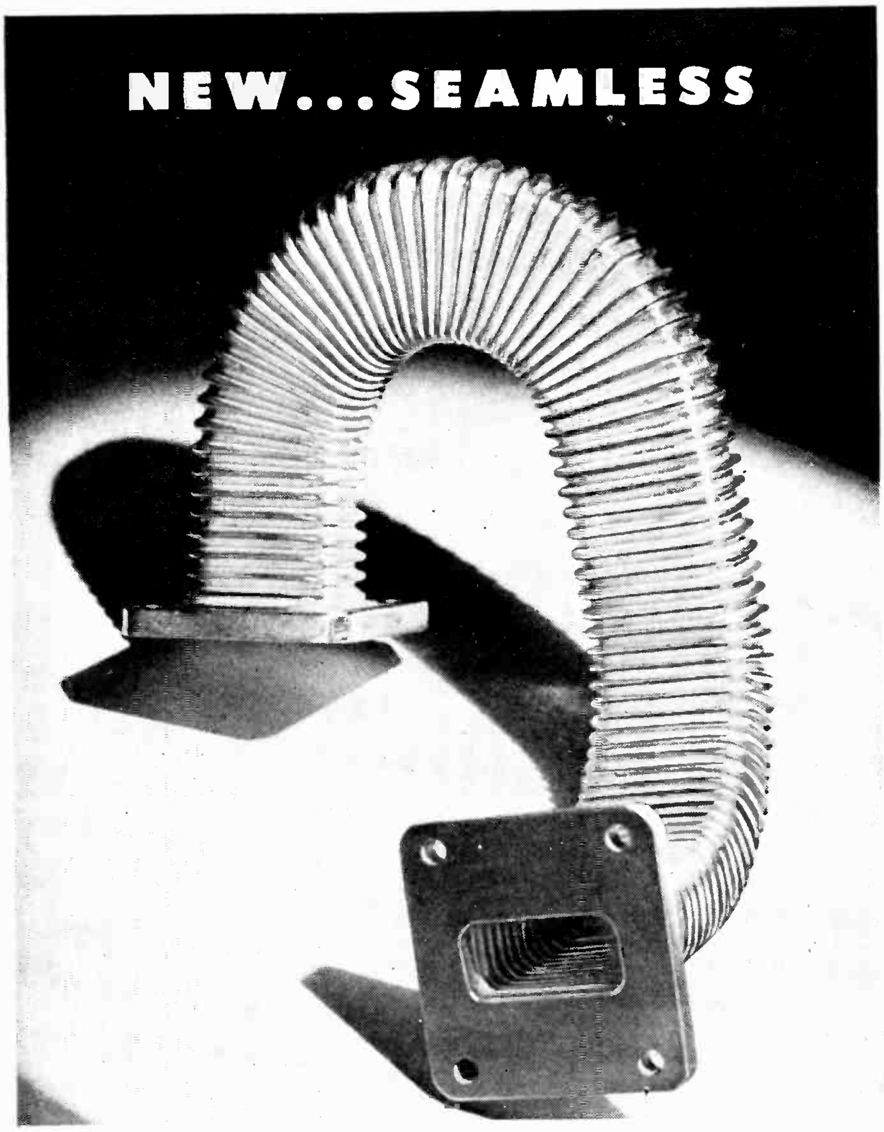
During the greater part of 1945, all development and production facilities of the RCA tube department, in common with virtually all other facilities of the company, were devoted to supplying the needs of our Armed Forces.

When peace returned to the world, the electron-tube industry was one of those which found itself in the fortunate position of having no major reconversion problems requiring modification of facilities.

A substantial expansion of business in the transmitter field is foreseen, principally resulting from construction of new television and frequency-modulation transmitters, but the bulk of the increase in demand for power tubes is expected to come ultimately from applications in nonradio electronic equipment.

High-frequency heating equipment for industry, for example, will require many times the power tubes currently employed in the radio broadcast industry. One company alone in the last year has installed high-frequency heating equipment to a total of some 10,000 kilowatts capacity, whereas the total rated output power of all broadcast stations in the United States is only 3700 kilowatts.

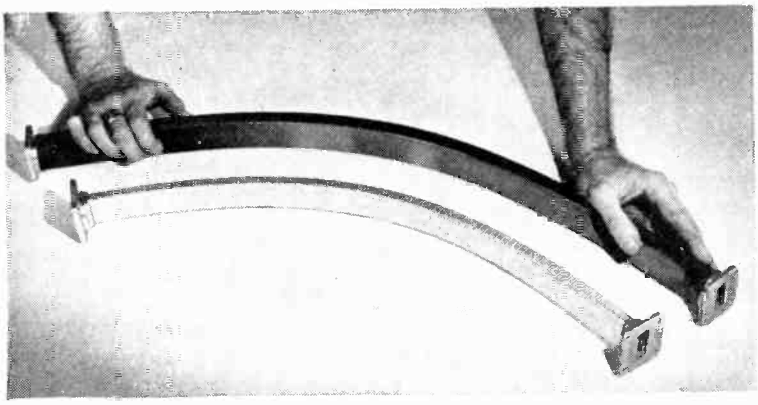
(Continued on page 75A)



Seamless Flexible Wave Guide made from thin-wall rectangular metallic tube. Can be extended, compressed, or bent in two planes to small radii. Withstands large number of flexures of moderate amplitude.

Vertebra type . . . a series of choke-plate wafers inserted in synthetic rubber jacket. Flexes easily, withstands large number of repeated deformations, such as bend, shear, twist, stretch or compression.

"Moldlock" type made of spirally wound, formed metallic strip with interlocked edges. Ordinarily furnished with rugged, pressure-tight synthetic jacket. Can be bent in any plane and twisted appreciably.



Now—for commercial use *Flexible* WAVE GUIDES

AMERICAN FLEXIBLE WAVE GUIDES are made in various types, mating electrically and mechanically with common sizes of rigid guide, for operation at wave lengths from 20 to less than 3 Cm.

These high precision units are suitable for use where relative motion is involved, such as with shock-mounted or vibrating units, to provide for misalignment, for the fabrication of complicated twists and bends, as flexible couplings to fragile components, and for other applications.

The various types of American Flexible Wave Guides differ principally in mechanical properties. We will gladly aid in selecting the most appropriate type, based on specific requirements of the installation.

Write for our "Electronics Data Book."

16359

ANACONDA
from mine to consumer

American
METAL HOSE

THE AMERICAN BRASS COMPANY
American Metal Hose Branch
General Offices: Waterbury 88, Connecticut
Subsidiary of Anaconda Copper Mining Company
In Canada: ANACONDA AMERICAN BRASS LTD.,
New Toronto, Ont.

INDUCTANCE CALCULATIONS SIMPLIFIED

At last, inductance calculations—so important to power, communication, and electrical engineers and those in related fields—have been reduced to simple, *slide-rule* computation.

INDUCTANCE CALCULATIONS

Working Formulas and Tables

By **FREDERICK WARREN GROVER, Ph.D.**

Professor of Electrical Engineering
Union College

Formerly Consulting Physicist
National Bureau of Standards

In this brand-new book all problems in inductance calculations are made easy and direct. The best single formula (or two for checking) has been chosen for every type of element or coil; and factors corresponding to dimensions of particular elements or coils are provided, so you can find the exact theoretical (not empirical) value by the most simple computations.

Included are tables that save the vast amounts of computation, often with complex mathematical functions, which hitherto have been necessary. Now all problems in inductance calculations can be computed by the use of interpolated values of constants, and even with the more complicated arrangements of conductors, a straightforward procedure can be outlined.

CHAPTER HEADINGS

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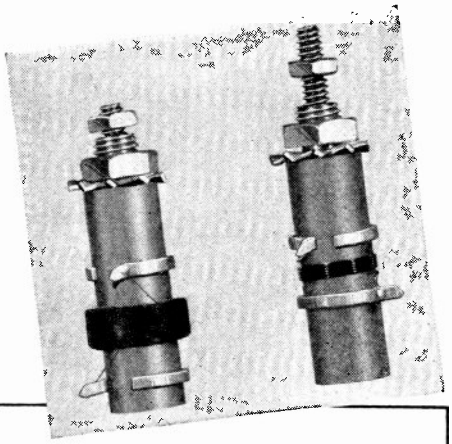

	Q	DC RESISTANCE	INDUCTANCE	VARIATION OF INDUCTANCE	TYPE & SIZE OF WIRE	NO. OF TURNS	TYPE OF WINDING
1 meg. unit	56	18.14 ohm @23°C.	420 microhenries ± 5%	325 to 750 microhenries	#38 SCE	198	Multiple
10 meg. unit	44	1.90 ohm @19.5°C.	8.4 microhenries ± 5%	4.75 to 14.25 microhenries	#38 SCE	24.5	Multiple
30 meg. unit	46	.126 ohm @20°C.	0.7 microhenries ± 5%	.350 to 1.0 microhenries	#28 E	7	Single layer
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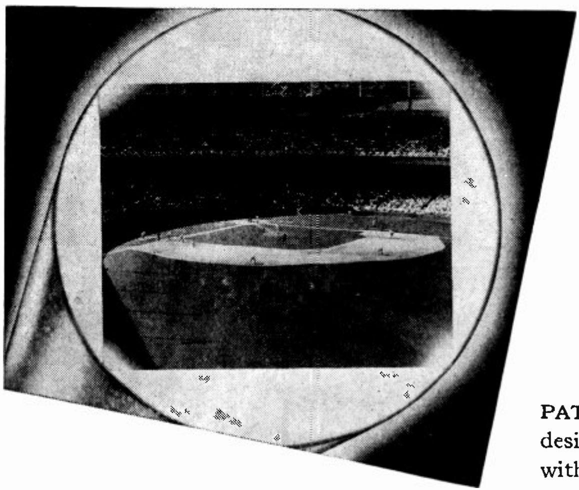

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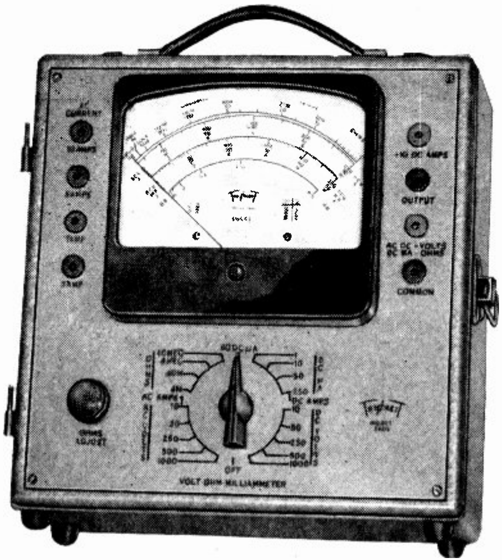

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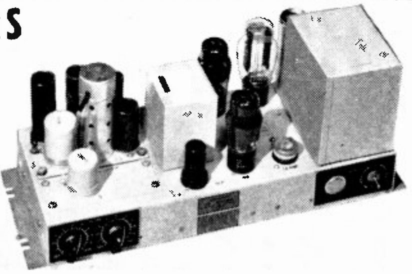

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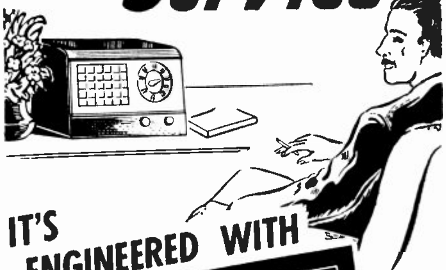

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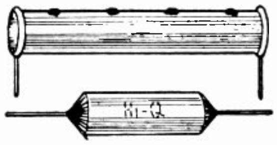

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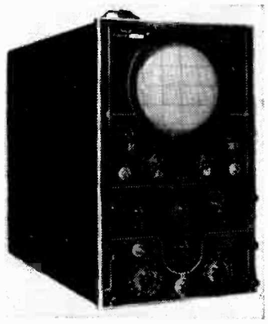

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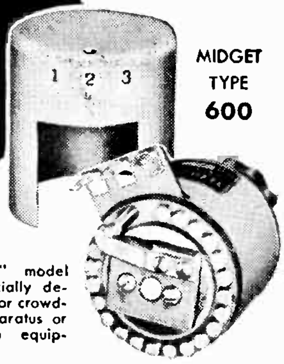

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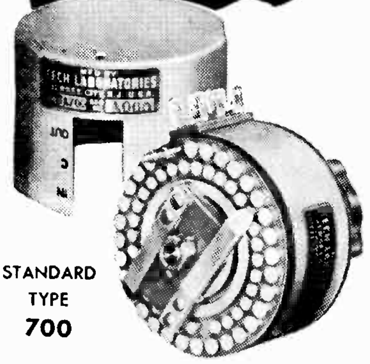

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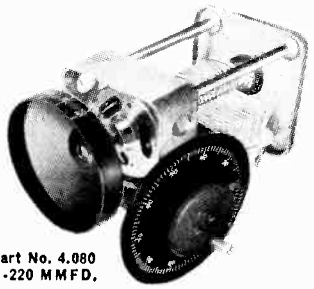

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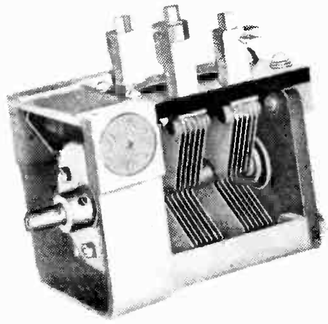

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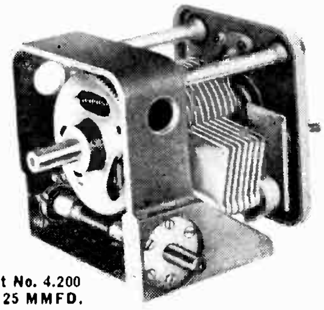

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New Fields For Tubes

(Continued from page 68A)

Special-type tubes, including the phototube group, found many important military applications during the war, and production and sales of such tubes rose to a peak about seven times their 1939 levels. Their potential field of peacetime applications is almost limitless, since electron tubes are now performing all of the functions of the five senses; there literally is no industry which cannot employ electronic devices to advantage in its operations.

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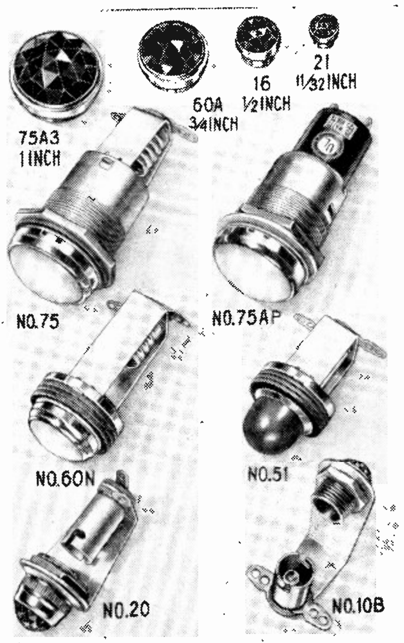

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  - ( ) B. Burglar Alarm & Protection Devices.
  - ( ) C. Combustion & Smoke Control Equipment.
  - ( ) D. Fire Prevention Equipment.
  - ( ) E. Photo-Electric Control Devices.
  - ( ) F. Variable Speed Motor Controlling Equipment.
- ( ) 28. EQUALIZERS.
- ( ) 29. FACSIMILE EQUIPMENT.
- ( ) 30. FILTERS:
  - ( ) A. Band Pass.
  - ( ) B. Noise Elimination.
  - ( ) C. Sound Effect.
- ( ) 31. FREQUENCY MEASURING EQUIPMENT:
  - ( ) A. Audio Frequency.
  - ( ) B. Primary Standards.
  - ( ) C. Radio Frequency.
  - ( ) D. Secondary Standards.
- ( ) 32. FREQUENCY MEASURING SERVICES.
- ( ) 33. FUSES & FUSE HOLDERS.

Generators:
- *A. Power: see Motor Generators.*
- *B. Signal: see Frequency Measuring Equipment, also Test Equipment.*

- ( ) 34. GRAPHIC RECORDERS.
- ( ) 35. HARDWARE:
  - ( ) A. Binding Posts.
  - ( ) B. Bushings.
  - ( ) C. Dials & Tuning Controls.
  - ( ) D. Flexible Shafts.
  - ( ) E. Lugs.
  - ( ) F. Screws.
  - ( ) G. Springs.
- ( ) 36. INDUCTION HEATING EQUIPMENT.
- ( ) 37. INDUCTORS.
- ( ) 38. INSULATION: (*Also see Ceramics.*)
  - ( ) A. Cloth.
  - ( ) B. Glass Seals.
  - ( ) C. Mica.
  - ( ) D. Varnished Cambric.
  - ( ) E. Paper.
- ( ) 39. JACKS.
- ( ) 40. KEYS:
  - ( ) A. Switching.
  - ( ) B. Telegraph.

Knobs, see Moulded Products.

- ( ) 41. LACQUERS:
  - ( ) A. Finishing.
  - ( ) B. Fungus Proofing.
  - ( ) C. Protecting.
  - ( ) D. Waterproofing.
- ( ) 42. LOUDSPEAKERS & HEADPHONES.

Lugs, see Hardware.

- ( ) 43. MACHINERY, FIXTURES, & TOOLS FOR RADIO & ELECTRONIC MANUFACTURING.
- ( ) 44. MAGNETS:
  - ( ) A. Electro.
  - ( ) B. Permanent.

Measuring Equipment, see Test Equipment.

- ( ) 45. METALS:
  - ( ) A. Copper.
  - ( ) B. Ferrous.
  - ( ) C. Non-Ferrous.
  - ( ) D. Precious & Rare.
- ( ) 46. METERS:
  - ( ) A. Ammeters.
  - ( ) B. Frequency Indicating.
  - ( ) C. Power Level.
  - ( ) D. Vacuum Tube Voltmeters.
  - ( ) E. Voltmeters.
  - ( ) F. Wattmeters.

Mica, see Insulations.

- ( ) 47. MICROPHONES.

- ( ) 48. MONITORING EQUIPMENT:
  - ( ) A. Frequency.
  - ( ) B. Modulation.
- ( ) 49. MOTOR-GENERATORS:
  - ( ) A. Dynamotors.
  - ( ) B. Motor-Generators.
  - ( ) C. Rotary-Converters.
- ( ) 50. MOTORS, VERY SMALL.
- ( ) 51. MOULDED PRODUCTS:
  - ( ) A. Cabinets.
  - ( ) B. Insulators.
  - ( ) C. Knobs, etc.
  - ( ) D. Plastic Parts.
  - ( ) E. Phenolic Sheet.
- ( ) 51A. OPTICAL SCREENS, MIRRORS AND MATERIALS.
- ( ) 52. OSCILLATORS:
  - ( ) A. Audio Frequency.
  - ( ) B. Radio Frequency.
  - ( ) C. Square Wave Generators.
- ( ) 53. OSCILLOGRAPHS & ACCESSORIES.
- ( ) 54. PANELS.
- ( ) 55. PHONOGRAPH PICK-UPS.
- ( ) 56. PILOT LIGHTS & ASSEMBLIES.
- ( ) 57. PLASTICS:
  - ( ) A. Raw Materials for Moulding.
  - ( ) B. Rods.
  - ( ) C. Sheets.
- ( ) 58. PLUGS.
- ( ) 59. POWER SUPPLIES.
- ( ) 60 PUMPS, VACUUM.
- ( ) 61. RACKS.
- ( ) 62. RADAR. *See Also Aircraft & Airport Equipment.*
- ( ) 63. RADIO RECEIVERS:
  - ( ) A. Broadcast.
  - ( ) B. Communications.
  - ( ) C. Fixed Frequency.
  - ( ) D. Frequency Modulation.
  - ( ) E. Special Purpose.
  - ( ) F. Television.
- ( ) 64. RECORD CHANGING MECHANISMS.
- ( ) 65. RECORDING EQUIPMENT & SUPPLIES:
  - ( ) A. Blanks.
  - ( ) B. Cutting Heads.
  - ( ) C. Magnetic Wire Recorders.
  - ( ) D. Needles.
  - ( ) E. Turntables & Machines.
- ( ) 66. RECORDING SERVICES.
- ( ) 67. RECTIFIERS:
  - ( ) A. Metallic.
  - ( ) B. Meter Rectifiers.
  - ( ) C. Vacuum Tube. *Also see Power Supplies.*

Regulators, Voltage, see Voltage Regulators.

- ( ) 68. RELAYS:
  - ( ) A. Keying.
  - ( ) B. Power.
  - ( ) C. Stepping.
  - ( ) D. Telephone Types.
  - ( ) E. Time Delay.
  - ( ) F. Vacuum Enclosed.
- ( ) 69. REMOTE CONTROLLING EQUIPMENT.
- ( ) 70. RESISTORS:
  - ( ) A. Fixed.
  - ( ) B. Precision.
  - ( ) C. Vacuum Sealed.
  - ( ) D. Variable.
  - ( ) E. Wire Wound.

Schools, see Technical Schools & Institutes.

Screws, see Hardware.

Shafts, see Hardware.

- ( ) 71. SOCKETS:
  - ( ) A. Receiving Types.
  - ( ) B. Transmitting Types.
- ( ) 72. SOLDER:
  - ( ) A. Cord.
  - ( ) B. Plain.

Speakers, see Loudspeakers.
Springs, see Hardware.

- ( ) 73. SWITCHES:
  - ( ) A. Circuit Breaking.
  - ( ) B. Key.
  - ( ) C. Power.
  - ( ) D. Receiver Wave Band Changing.
  - ( ) E. Rotary.
  - ( ) F. Time Delay.
  - ( ) G. Transmitter Wave Band Changing.
- ( ) 74. TECHNICAL SHOOLS & INSTITUTES.
- ( ) 73. TESTING & MEASURING EQUIPMENT:
  - ( ) A. Bridges.
  - ( ) B. Capacitor Testing Equipment.
  - ( ) C. Inductance & "Q" Testing Equipment.
  - ( ) D. Resistance Testing Equipment.
  - ( ) E. Vacuum Tube Testing Equipment.
  - ( ) F. Wave Form Analyzers & Distortion Testing Equipments.
- ( ) 76. TRANSCRIPTION LIBRARIES.
- ( ) 77. TRANSFORMERS:
  - ( ) A. Audio Frequency.
  - ( ) B. Hermetically Sealed Types.
  - ( ) C. High Fidelity Audio Types.
  - ( ) D. Power Components.
  - ( ) E. Pulse Generating Types.
  - ( ) F. Radio Frequency.
- ( ) 78. TRANSMITTERS:
  - ( ) A. Amplitude Modulation.
  - ( ) B. Communication.
  - ( ) C. Frequency Modulation.
  - ( ) D. Policy & Emergency Equipment.
  - ( ) E. Television.
  - ( ) F. Ultra-High Frequency.
- ( ) 79. ULTRA-HIGH FREQUENCY ACCESSORY EQUIPMENT:
  - ( ) A. Antennas & Reflectors.
  - ( ) B. Measuring & Test Equipment.
  - ( ) C. Tuning Elements.
  - ( ) D. Wave Guides.
- ( ) 80. VACUUM TUBES:
  - ( ) A. Cathode Ray.
  - ( ) B. Geiger Mueller.
  - ( ) C. Industrial Types.
  - ( ) D. Klystrons & Magnetrons.
  - ( ) E. Receiving Types.
  - ( ) F. Rectifiers.
  - ( ) G. Special Purpose & Phototubes.
  - ( ) H. Television Tubes.
  - ( ) I. Transmitting types.
  - ( ) J. Voltage Regulator.

Varnishes, see Lacquers.

- ( ) 81. VIBRATORS, POWER SUPPLY.
- ( ) 82. VOLTAGE REGULATORS:
  - ( ) A. Automatic.
  - ( ) B. Manually Controlled.
- ( ) 83. WAXES & SEALING COMPOUNDS.
- ( ) 84. WIRE:
  - ( ) A. Copper.
  - ( ) B. Precious Metal.

Product Classification If Not Included In List

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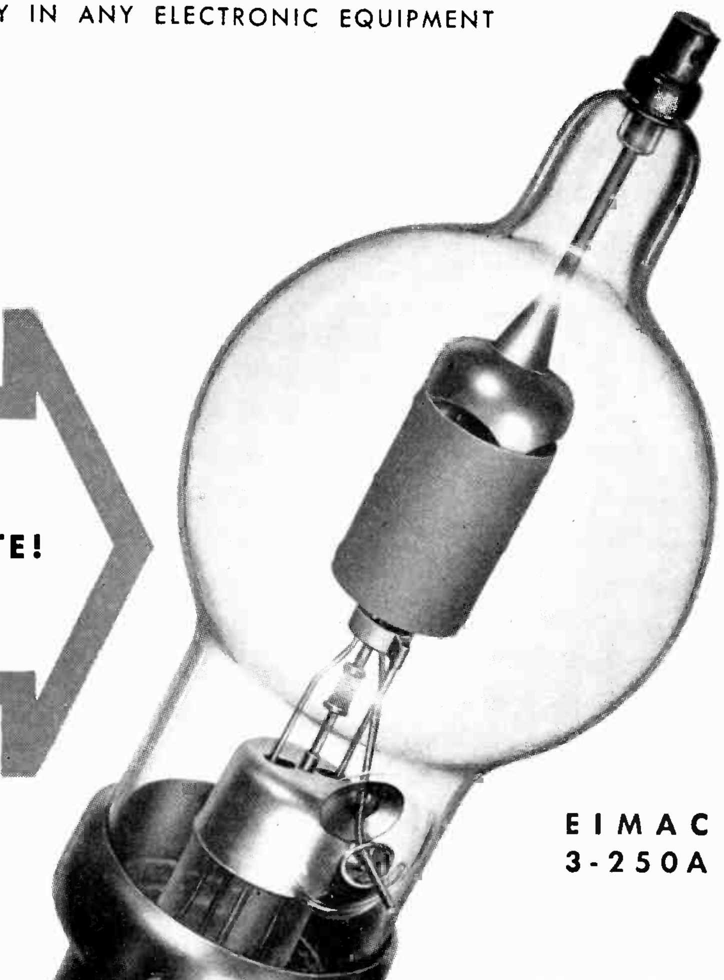

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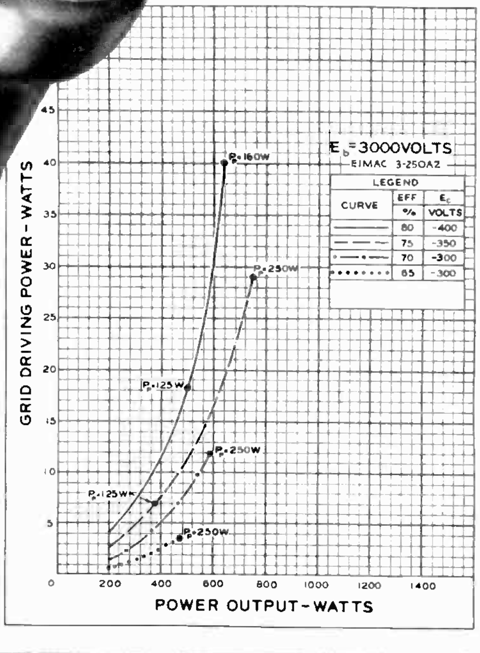

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Amplification Factor (Average)	14	37
Direct Interelectrode Capacitances (Average)		
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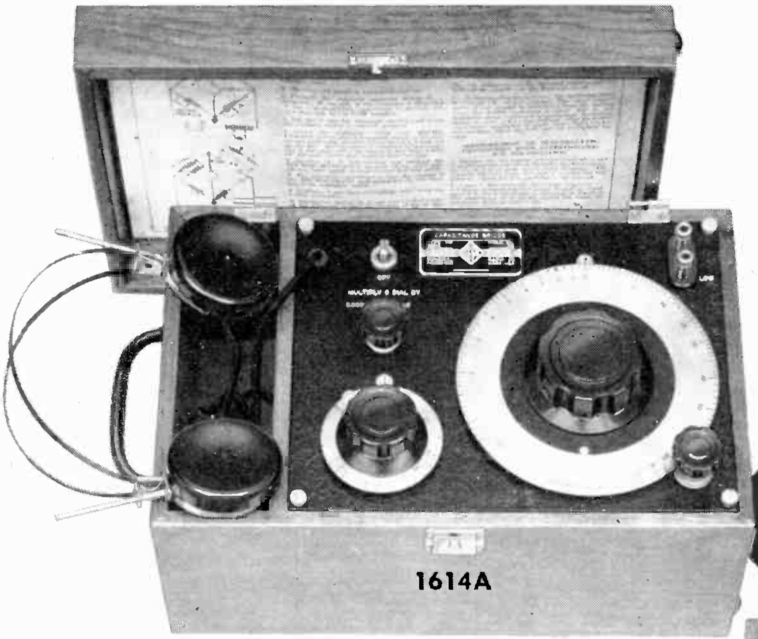

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TYPE 1614-A CAPACITANCE BRIDGE

RANGE for Capacitance: 10 micromicrofarads to 100 microfarads in three steps; 10 micromicrofarads to 10,000 microfarads; 0.01 microfarad to 1.0 microfarad and 1.0 microfarad to 100 microfarads. **ACCURACY:** ±2% except on lowest range where, after zero of 9 microfarads is subtracted, accuracy is ±2 microfarads +2% of dial reading. **DIAL CALIBRATION:** approximately logarithmic over two main decades, with compressed lower decade used for measurements below 100 microfarads. **RANGE** for Dissipation Factor: 0 to 45%. **FREQUENCY.** 1000 cycles ±5% from internal oscillator. **ACCESSORIES REQUIRED:** if a d-c polarizing voltage is used a 2 microfarad blocking condenser is required. Space is provided in the cabinet for such a condenser, not supplied with the instrument. **Price: $105.00**

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RANGE for Inductance: 10 microhenries to 100 henries in 3 steps of 10 microhenries to 10,000 microhenries; 0.1 henry to 1 henry and 1 henry to 100 henries. **ACCURACY:** ±2.5% of dial reading between 100 microhenries and 10 henries. Below 100 microhenries the error varies inversely as the magnitude of the unknown. **DIAL CALIBRATION:** approximately logarithmic over two main decades with a compressed lower decade for measurements below 100 microhenries. **RANGE** for Q (storage factor): 1 to 45. Other specifications are the same as those for the Type 1614-A Capacitance Bridge. **Price: $115.00**

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