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.

Pulse-Type Angular-Velocity Modulation
Current Distribution for Broadside Arrays
High-Impedance Cable
Locking Phenomena in Oscillators

Waves and Electrons Section
Aspects of Specialization
Television-Guided Missiles
Cathode-Coupled Amplifier

The Institute of Radio Engineers
Foremost Manufacturers of Transformers
to the ELECTRONIC INDUSTRY

United Transformer Corp.

150 VARICK STREET
NEW YORK 13, N.Y.

EXPORT DIVISION: 13 EAST 40th STREET, NEW YORK 16, N.Y., CABLES: "ARLAB"
HOW MYCALEX BUILDS BETTER PEACETIME PRODUCTS

As high frequency insulating standards become more exacting, the more apparent become the many advantages of MYCALEX over other types of materials...in building improved performance into electronic apparatus.

For 27 years MYCALEX has been known as "the most nearly perfect" insulation. Today improved MYCALEX demonstrates its superior properties wherever low loss factor and high dielectric strength are important...where resistance to arcing and high temperatures is desired...where imperviousness to oil and water must be virtually 100%.

New advancements in the molding of MYCALEX now make available the production of a wide variety of parts with metal inserts or electrodes molded in to create a positive seal.

It pays to become familiar with the physical and electrical properties of all three types of MYCALEX — MYCALEX 400, MYCALEX K and MYCALEX 410 (MOLDED). Our engineers invite your inquiries on all insulating problems.

MYCALEX CORPORATION OF AMERICA

"Owners of 'MYCALEX' Patents"

Plant and General Offices, CLIFTON, N. J. Executive Offices, 30 ROCKEFELLER PLAZA, NEW YORK 20, N. Y.
1920 Loop antenna for 400-500 meter ship-to-ship radio telephone receivers. Its design enabled earliest measurements of field strength.

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

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

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

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

1938 Narrow beam and rapid scanning gave high accuracy to big Navy guns.

1941 Polyrod radar antenna was an important war contribution. Helped sink many U-Boats, 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.
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, Jonas 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.

**BELLS 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.
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.

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.

---

**RATINGS**

| Filament voltage | 6.3 v |
| Filament current | 250 amp |
| Interelectrode capacitance | 11,000 micromhos |
| 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 3mc): 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.**
Receiving Diversity Tone Keyer

**Designed, Engineered**

**and Built to Work**

**for the World's Most**

**Critical Employer . . .**

**The International Press**

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 wpm
- 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 CORP.**

Executive Offices: 38-01 35th Avenue, Long Island City 1, New York

Proceedings of the I.R.E. and Waves and Electrons June, 1946
Amphenol Twinax and Coax RG cables, produced to standards that surpass the high Army-Navy specifications for critical wartime uses, are ideal for the myriad of peacetime applications in all phases of the rapidly expanding electronic industries. Rigid laboratory tests and notarized affidavits on every shipment give final assurance of extra quality and dependability.

- Amphenol special low-loss V.H.F. connectors are available in a complete line for all practical applications of RG cables and other uses. Mechanically efficient and electrically correct, these easily assembled connectors and adapters provide the utmost efficiency in circuits in which they are used.

**AMPHENOL ASSEMBLY SERVICE**

An important part of Amphenol service to users of cables and connectors is a complete Assembly Service. Rigid specifications and performance requirements, plus thorough scientific testing of each part and process, assures users of satisfactory service. For cables, connectors and complete assembly service, look to the world’s largest producer – Amphenol.

**AMERICAN PHENOLIC CORPORATION**

CHICAGO 50, ILLINOIS

IN CANADA

AMPHENOL LIMITED • TORONTO

**AMPHENOL**
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.

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.

**THE WILCOX TYPE 255A RECEIVER**

- 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.

**WILCOX ELECTRIC COMPANY, INC.**

Manufacturers of Radio Equipment
FOURTEENTH AND CHESTNUT
KANSAS CITY, MISSOURI
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 15,000 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.
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 the Federal's sales director, Norman E. Wunderlich, 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, started 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 new "FREQUEMATIC" modulator, an exclusive feature of Federal's 1, 3, 10, 20, 50 kw transmitters, exceeded 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

Export Distributor:
International Standard Electric Corporation
Proceedings of the I.R.E. and Waves and Electrons June, 1946
Newark 1, New Jersey
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.
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.

**AGAIN HYTRON’S LONG EXPERIENCE**

**GIVES YOU THE BEST...**

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 inter-electrode 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.
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.

FOR RADIO-ELECTRONIC AND INDUSTRIAL APPLICATIONS
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 33 1/3 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.
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

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.
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 .. Cineh 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 as balance between radio frequency sensitivity and power output is concerned.

TABLE 1

<table>
<thead>
<tr>
<th>TUBE FUNCTION</th>
<th>VACUUM TUBE FILAMENT COMBINATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(A)</td>
</tr>
<tr>
<td>R. F. Amplifier</td>
<td>1.5</td>
</tr>
<tr>
<td>First Detector</td>
<td>1.5</td>
</tr>
<tr>
<td>I. F. Amplifier</td>
<td>1.5</td>
</tr>
<tr>
<td>I. F. Amplifier</td>
<td>—</td>
</tr>
<tr>
<td>Second Detector</td>
<td>1.5</td>
</tr>
<tr>
<td>Audio Output</td>
<td>3.0</td>
</tr>
<tr>
<td>Total &quot;A&quot; Voltage</td>
<td>9.0</td>
</tr>
</tbody>
</table>

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 estimate the maximum 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 assure 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.

TABLE 2

<table>
<thead>
<tr>
<th>SERVICE ESTIMATES—No. 754 &quot;A-B&quot; PACK—USED FOUR HOURS PER DAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>INITIAL &quot;A&quot; DRAIN</td>
</tr>
<tr>
<td>50 m.a.</td>
</tr>
<tr>
<td>200 Hours</td>
</tr>
<tr>
<td>INITIAL &quot;B&quot; DRAIN</td>
</tr>
<tr>
<td>10 m.a.</td>
</tr>
<tr>
<td>210 Hours</td>
</tr>
<tr>
<td>12 m.a.</td>
</tr>
<tr>
<td>15 m.a.</td>
</tr>
</tbody>
</table>

* 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
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!
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.

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

ENGINEERING SERVICE OFFICES:
ST. LOUIS, Mo., 1123 Washington Ave., Tel. Garfield 4959 • NEWARK, N. J., 1013 Wise Bldg., Tel. Mitchell 2-8159
CAMBRIDGE, Mass., 38 R 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

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

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.

PROCEEDINGS OF THE I.R.E. AND WAVES AND ELECTRONS

June, 1946
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 rugg-
edness, 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 pro-
duction men in working out the most economical and efficient
applications.

Proceedings of the I.R.E. and Waves and Electrons  June, 1946
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 VT Fuze.

Since VT 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.

RAYTHEON MANUFACTURING COMPANY

Excellence in Electronics

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

Proceedings of the I.R.E. and Wave and Electrons  • June, 1946
Precision grinding of fired ceramic parts assures uniformity.

Electrolimit gauging checks dimensions to the fifth decimal.

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.
NEW -hp- DISTORTION ANALYZER
continuously 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 detector 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.

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

Proceedings of the I.R.E. and Waves and Electrons June, 1946
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.

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

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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.

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more efficient ...in miniature

TUNG-SOL vibration-tested ELECTRONIC TUBES
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.

POWRR-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

Proceedings of the I.R.E. and Waves and Electrons June, 1946
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.

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

**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.

<table>
<thead>
<tr>
<th>SCALE</th>
<th>DIVISIONS</th>
<th>ROTATION</th>
<th>DIRECTION OF CONDENSER ROTATION</th>
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<tr>
<td>2</td>
<td>0-100</td>
<td>180°</td>
<td>Counter Clockwise</td>
</tr>
<tr>
<td>3</td>
<td>100-200</td>
<td>180°</td>
<td>Clockwise</td>
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<tr>
<td>4</td>
<td>200-300</td>
<td>270°</td>
<td>Clockwise</td>
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<tr>
<td>5</td>
<td>300-400</td>
<td>360°</td>
<td>Clockwise</td>
</tr>
<tr>
<td>6</td>
<td>0-150</td>
<td>360°</td>
<td>Counter Clockwise</td>
</tr>
</tbody>
</table>
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.

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

GENERAL CHARACTERISTICS

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

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

MACHLETT
APPLIES TO RADIO AND INDUSTRIAL USES
ITS 45 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.
NEW EBY SOCKETS
Lock-In, Octal, and Non-Microphonic

LOCK-IN
(Glass Bonded Mica)
Chassis Hole—1\(\frac{1}{4}\)" dia.
Mounting Centers—1\(\frac{3}{4}\)"
Mounting—Top or Bottom

LOCK-IN
Chassis Hole—1\(\frac{1}{4}\)" dia.
Mounting Centers—1\(\frac{3}{4}\)"
Mounting—Top or Bottom

LOCK-IN
Chassis Hole—1\(\frac{1}{4}\)" dia.
Mounting Centers—1\(\frac{3}{4}\)"
Mounting—Top or Bottom

With or without Grounding Lugs

OCTAL
Chassis Hole—1\(\frac{1}{4}\)" dia.
Mounting Centers—1\(\frac{3}{4}\)"
Mounting—Top or Bottom

With or without Grounding Lugs

NON-MICROPHONIC
(Miniature)
Chassis Hole—\(\frac{3}{16}\)" dia.
Mounting Centers—\(\frac{7}{8}\)"
Mounting—Top or Bottom

Write today for complete details...
THE RCA-8D21 Push-Pull Power Tetrode for television and FM broadcasting service is a radical departure from previous transmitting tube designs in that high-power capability at very high frequencies is achieved through the use of an exceedingly compact, high-current-density structure in which all electrodes are water-cooled close to the active electrode areas... resulting in a concentration of power in a tube only 12 inches in over-all height and 5¾ inches in diameter!

The structure features a thoria-coated, multi-strand filament; low inter-electrode capacitances; excellent internal shielding between input and output circuits; internal neutralization of the small feedback capacitance to eliminate need for external neutralization; internal by-passing of screen to filament to maintain the r-f potential of the screen at ground potential; and relatively short internal leads with consequent low inductances.

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

When used as a Class C, grid-modulated, push-pull, r-f amplifier in television service, the 8D21 has a maximum plate-voltage rating of 6000 volts, a maximum total plate input of 10,000 watts, and a total plate dissipation of 6000 watts. It may be operated with maximum rated input as high as 300 Mc.

A technical bulletin on the RCA-8D21 is available on request. RCA Tube Applications 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.

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.
PROCEEDINGS OF THE I.R.E.
AND
WAVES AND ELECTRONS
Published Monthly by
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PROCEEDINGS OF THE I.R.E.

There Is Always Room at the Top ............................................. W. C. White ................................ 326
Frank H. R. Pounsett—Chairman, Toronto Section, 1946 .................. 327
A New Angular-Velocity-Modulation System Employing Pulse Techniques .................................................. James P. Gordon .................................. 328
A Current Distribution for Broadside Arrays Which Optimizes the Relationship Between Beam Width and Side-Lobe Level . . C. L. Dolph ........................................ 335
High-impedance Cable ............................................................. Heinz E. Kallmann ......................... 348
A Study of Locking Phenomena in Oscillators ............................... Robert Adler .................................. 351
Correspondence:
“A Correction Formula for Voltmeter Loading” ............................ Raymond E. Lafferty ......................... 358
Contributors to PROCEEDINGS OF THE I.R.E. ............................. ........................................ 359

INSTITUTE NEWS AND RADIO NOTES

Chicago Section Engineering Conference ...................................... 360
I.R.E. People ........................................................................ 362
Sections ................................................................................. 364
Institute Committees—1946 ......................................................... 366
Technical Committees—1946—1947 ............................................... 367
Institute Representatives in Colleges—1946 ..................................... 368
Institute Representatives on Other Radio—1946 ............................... 368

WAVES AND ELECTRONS

SECTION

Joseph General—Secretary-Treasurer, Dayton Section, 1946 .......... 369
The Engineer and Social Co-ordination ...................................... H. T. Kohlhaus ......................... 370
Commercial Applications of Wartime Science .............................. G. L. Van Dusen ......................... 371
Some Broad Aspects of Specialization ....................................... E. Finley Carter ......................... 372
Television Equipment for Guided Missiles .................................. Charles J. Marshall and Leonhard Katz ............... 375
The Cathode-Coupled Amplifier ................................................. Reats A. Pullen, Jr ..................... 402
Contributors to WAVES AND ELECTRONS Section ................... ........................................ 406
Abstracts and References from Wireless Engineer ........................ 407
Section Meetings ..................................................................... 38A Positions Open .......................... 50A
Membership ........................................................................... 42A Positions Wanted ...................... 50A
Advertising Index .................................................................. 78A

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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 R.M.I 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.

Consider the well-known multivibrator circuit of Abraham and Bloch.

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, 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.

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.

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.

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.

---

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

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

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.

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.

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 V1, and the audio modulating voltage to the grid of V2. The output is taken from the V1 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 V2 will not unduly load a 500-ohm input to it through the decoupling resistor R10 (see Fig. 12). In a like manner, the input circuit is prevented from reacting on the multivibrator. The degeneration accomplished across the V2 cathode resistor is desirable. By using a suitable radio-frequency choke in place of R10, 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 V1 grid negative (Fig. 18(c)) causing V1 anode to go positive, which drives V2 grid positive firing V2, which maintains V1 grid negative for a period depending upon the circuit time constants and the grid biases. The V1 grid bias eventually leaks off and V1 grid goes positive, firing V1. The action is now reversed and V1 remains conducting, due to its positive grid, until another pulse arrives to trigger V1 grid negative.

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 V1 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 V1 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 R1 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 V₂ took place during the multivibrator switch-over period (i.e., during the time V₂ grid was going from negative to positive), this switch-over time would be altered. For a part of the time during a modulation cycle V₂ 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 V₂ is conducting is high, then large grid current will flow in the V₂ 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 V₂ 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 V₂ goes from saturation to cutoff. The relationship between a positive pulse which is originally derived from the output of V₁ anode and the period during which V₂ goes from saturation to cutoff is shown in Fig. 14.

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 V₁ grid as possible, and as low a grid resistance as will still permit good operation. Separate bias adjustments were provided for both V₁ and V₂ grids for optimum adjustment.

This circuit functions fundamentally as the previously described circuit with the exception that the anode of V₂ connects directly to the positive bus such that multivibrator coupling to V₁ is by means of the cathode circuit only.

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.

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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 V1 grid.
(c) Conditions on V1 grid showing how the blocking-oscillator pulse initiates the multivibrator cycle.
(d) Conditions on V1 anode.
(e) The differentiated output from V1 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-kilicycle 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.

**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.

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. 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.

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. 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.

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.

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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 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 \( (a+b)^N \). 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, utilizing for the first time a correspondence between the roots 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
case there is. These two different types with the appropriate values of $I_0$ corresponding to the various point sources are shown in Figs. 1 and 2, respectively. In either case, let the center of the array be taken as the phase reference point, let $d$ denote the constant spacing between the point sources, let $\theta$ denote the angle between the direction of the field to distant point $P$ and the normal to the array. Let $I_0$ 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

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

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

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

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

$$u = \frac{d\pi}{\lambda} \sin \theta,$$

(1) and (2) become respectively

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

and

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

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 $-1 \leq x \leq 1$. To obtain the polynomial form, use is made of the fact that

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

from which it follows that

$$\cos nu = \cos^n u - \left( \begin{array}{c} n \\ 2 \end{array} \right) \cos^{n-2} u \sin^2 u + \ldots \right)$$

$$= \sum_{k=0}^{n} \left( \begin{array}{c} n \\ k \end{array} \right) \cos^{n-k} u \sin^k u + \ldots$$

where

$$\left( \begin{array}{c} n \\ k \end{array} \right) = \frac{n!}{k!(n-k)!}.$$  

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 $xP_{N-1}(x)$ 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 $d/\lambda$ ratio. That is, if $d/\lambda$ equals one, then the range of the variable $u$ is clearly from $0 \leq u \leq \pi$. On the other hand, if $d/\lambda$ is one half, then the range of $u$ is $0 \leq u \leq \pi/2$. Since $\cos u$ in the range $0 < u < \pi/2$ is the negative of $\cos (\pi - u)$ in the range $\pi/2 < u < \pi$, it is clear that it is sufficient to compute either (4) or (5) in the range $0 < u < \pi/2$ and to use the recursion formula

$$F(u) = F(\pi - u)$$

corresponding to (4) and (5) respectively in order to obtain the pattern as a function of $u$ over the range $0 \leq u \leq \pi$. Similar formulas are obvious if $d/\lambda$ exceeds one. However, the range $0 \leq u \leq \pi/2$ corresponds to half-wave spacing while the range $0 \leq u \leq \pi$ 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 $0 \leq u \leq \pi/2$ 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 $\theta = 90$ degrees while $u = \pi$ corresponds to $\theta = 90$ degrees, the fundamental pattern of (4) and (5) occurs first in the 0- to 30-degree range and is then repeated in reverse order in the 30- to 90-degree range on $\theta$ 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 \( 0 \leq u \leq \pi/2 \) 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 \( 0 \leq u \leq \pi/2 \). The recursion formula (7), or others similar to it for values of \( d/\lambda \) greater than one, are then sufficient to give the pattern as a function of \( u \) corresponding to the \( d/\lambda \) 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 \( d/\lambda \) 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

\[
\cos (2n + 1)u = \sum_{m=0}^{n} A_{2m+1}2^{n+1}x^{2m+1}
\]

where

\[
A_{2m+1}2^{n+1} = (-1)^{n-m} \sum_{p=-m}^{n} \binom{p}{n-m} (2n + 1) 2^p
\]

and that

\[
\cos 2nH = \sum_{m=0}^{n} A_{2m}2^{n}x^{2m}
\]

where

\[
A_{2m}2^{n} = (-1)^{n-m} \sum_{p=-m}^{n} \binom{p}{n-m} (2n) 2^p.
\]

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

\[
G_{2N-1}(x) = \sum_{k=0}^{N} I_k \left\{ \sum_{m=1}^{k} A_{2m-1}2^{k-1}x^{2m-1} \right\}
\]

and

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

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

\[
G_{2N-1}(x) = \sum_{q=1}^{N} I_q \sum_{k=1}^{q} A_{2q-1}2^{k-1}x^{2q-1}
\]

and

\[
G_{2N}(x) = \sum_{q=0}^{N} I_q A_{2q}2^{q}x^{2q}.
\]

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

\[
G_3(x) = F_4(u) = x^1 \left( 4I_2x^2 + (I_1 - 3I_2) \right)
\]

where \( x = \cos u \), \(-1 \leq x \leq 1\).

The nulls therefore occur at \( x = 0 \) and at

\[
x_0 = \pm \sqrt{\frac{3 - I_1}{I_2} \frac{I_1}{4}}.
\]

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

\[
\frac{dx}{du} = - \sin u = 0
\]

and the positions of the other side lobes by

\[
x = \pm \sqrt{\frac{3 - I_1}{I_2} \frac{I_1}{12}}.
\]

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

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

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 \( 1 \leq I_1/I_2 \leq 3 \) 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 $0 \leq I_1/I_2 \leq 1$. 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 by

$$T(z) = \cos(n \arccos z)$$

(15)

To see that these are indeed polynomials of degree $n$ in $z$, set $4 = \arccos z$ and use (6). The nulls of these polynomials are given by the roots of $\cos n4 = 0$, or by

$$\theta_k^0 = (2k - 1)\pi/2n$$

(16)

Further, $T_{n+1}(z) = 0$ whenever $\sin n\phi = 0$, or when

$$\theta_k^0 = k\pi/n, \quad k = 1, 2, \ldots, n$$

(17)

At the points $\theta_k$, let $z_k = \cos \theta_k$. Then $|T_n(z_k)| = 1$. If one uses (15) as the definition, then clearly $-1 \leq z \leq 1$. However, considered as a polynomial in $z$, $T_n(z)$ exists for all $z$, $-\infty \leq z \leq \infty$. 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, $T_n(\phi_k)$ only vanish for any $k$, $k = 1, 2, \ldots, n$ in the interval between $-1 \leq z \leq 1$. 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:

$$T_{2N-1}(z) = \sum_{q=1}^{N} A_{2q-1}^{N-1}z^{2q-1} = -\infty \leq z \leq \infty$$

(18)

$$T_{2N}(z) = \sum_{q=0}^{N} A_{2q}^{2N}z^{2q} = -\infty \leq z \leq \infty$$

(19)

Now if the range of $z$ is restricted to $-z_0 \leq z \leq z_0$, 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 $x = \cos \theta$.

Written in terms of $x$, $-1 \leq x \leq 1$, (18) and (19) become

$$T_{2N-1}(z_0x) = \sum_{q=1}^{N} A_{2q-1}^{N-1}z_0^{2q-1}x^{2q-1}$$

(20)

and

$$T_{2N}(z_0x) = \sum_{q=0}^{N} A_{2q}^{2N}z_0^{2q}x^{2q}$$

(21)

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

$$\sum_{k=0}^{N} I_k A_{2q-1}^{2q-1} = .1_{2q-1}^{2N-1}z_0^{2q-1}, \quad q = 1, \ldots, N.$$  

These may be written in the form

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

(22)

Similarly equating (21) to (13) yields

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

(23)

It is clear that (22) and (23) can be solved for $I_q$, $q = 1, \ldots, N$ 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

$$T_{N}(z_0) = r; \quad z_0 = \cos(\pi/2M)$$

(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

$$u = \arccos \left( \frac{\cos \phi_k}{z_0} \right); \quad k = 1, 2, \ldots, N$$

(25)

where $\phi_k$ are given by (16) and $u$ by (3).

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

$$u = \arccos \left( \frac{\cos \theta_k}{z_0} \right); \quad k = 1, 2, \ldots, N$$

(26)

where $\theta_k$ is given by (17).

(d) The pattern between the nulls is given by

$$F(u) = \cos \left\{ M \arccos \left( \frac{z_0 \cos u}{z_0} \right) \right\}$$

(27)

or by

---

\[ E(\theta) = \cos \left\{ \frac{\pi}{2M} \arccos \left[ \frac{x_0 \cos \left( \frac{\pi d}{\lambda} \sin \theta \right)}{x_0^b} \right] \right\}. \]

In the second case, if the first null is specified as \( \theta_0 \), it is necessary to compute \( x_0^b \) from

\[ x_0^b = \cos \theta_0 = \cos \left( \frac{\pi d}{\lambda} \sin \theta_0 \right) \]

and to choose \( z_0 \) from the relation

\[ z_0 = \frac{1}{x_0^b} \cos \frac{\pi}{2M} \]

so that

\[ T_M(z_0 x) = T_M \left[ \left( \frac{\cos \frac{\pi}{2M}}{x_0^b} \right) \right] \]

will possess the necessary null at \( x_0^b \). 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 \( (n+1):1 \) and 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:**

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

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
   \[ |P(x)| \leq a \text{ whenever } |x| \leq |x_0| \leq 1. \]

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 \( x_0 \) within \( |x| \leq x_0 \).

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

\[ T_n(z_0) = 1 ; \quad z_0 \geq \cos \left( \frac{\pi}{2M} \right). \]

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

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

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

\[ Q(x) = MT_n\left( \frac{z_1^0 x}{x_0} \right); \]

\( Q(x) \) 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 \(-x_0 \leq x \leq x_0 \).

Now it will be shown that

\[ \max |Q(x)| < \max |P(x)| \]

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

\[ \max |Q(x)| \geq \max |P(x)| \]

when \( |x| \leq |x_0| \). Form the difference polynomial

\[ D(x) = Q(x) - P(x) \]

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

\[ D(1) = 0, \quad D(-1) = 0, \quad D(x_0) = 0. \]

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

\[ D(x_k) \leq 0, \quad D(x_k) \geq 0, \quad D(x_{k+1}) \leq 0. \]

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

\[ b = \max |Q(x)| < \max |P(x)| |x| \leq |x_0| < 1. \]

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

\[
u = \arccos \left( \frac{z_0'}{z_0} \right).\]

(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 \( \theta \), or \( \theta \) may be found directly from

\[
\theta = \arcsin \left( \frac{\lambda}{\pi d} \arccos \left( \frac{z_0'}{z_0} \right) \right).\]

(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

\[
G_7(x) = x^4 [64I_4 x^4 + (16I_3 - 112I_4)x^2 + (4I_2 - 20I_3 + 56I_4)] \quad \text{for} \quad x^2 \leq 1.
\]

Furthermore, from Appendix I, if \( \phi = \arccos z \), then

\[
T_7(z) = \begin{cases} 
2 [64z^4 - 112z^2 + 56z^2 - 7] & \text{if} \quad -1 \leq z \leq 1 \\
\cos 7\phi & \text{if} \quad |z| > 1.
\end{cases}
\]

(32)

The following set of equations corresponding to (22) result when \( G_7(x) \) is equated to \( T_7(z_0 x) \):

\[
\begin{align*}
I_4 &= z_0^4 \\
I_3 &= 7I_4 - 7z_0^3 \\
I_2 &= 5I_3 - 14I_4 + 14z_0^2 \\
I_1 &= 3I_2 - 5I_3 + 7I_4 - 7z_0.
\end{align*}
\]

(33)

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](image)

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

![Fig. 4](image)
wavelength ratios \((d/\lambda)\) 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 rows one and two give the position of the nulls as a function of \(\phi_k\) from (16);

row three gives the computed values of the nulls as a function of \(\cos \phi_k\);

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 \(\theta\) for \(d/\lambda = 1\) and \(d/\lambda = \frac{1}{4}\), 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>
<thead>
<tr>
<th>(z_0 = 1.14)</th>
<th>Side Lobe Level = 25.8 decibels</th>
</tr>
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<tbody>
<tr>
<td>(\phi_k)</td>
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<tr>
<td>(\phi_k)</td>
<td>(\phi_k)</td>
</tr>
</tbody>
</table>

Table I: 8-Element Array
This locates the half-power points in terms of \( x \) at 
\( x = \pm 1.116/1.14 = \pm 0.9789 \). Since \( u = \arccos x \), 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 
halflower points. For \( d/\lambda = 1/2 \), the above values of \( u \) give a 
value of \( \theta = 7.5 \) degrees, or an estimated total beam width at the 
halflower points of 15 degrees.

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

It must be re-emphasized that, from the design view-
point, all of the calculations tabulated in Table I are 
unnecessary, except perhaps the determination of the 
beam width at the halflower points. That is, prac-
tically, if the current distribution can be chosen to place 
the side lobe at an arbitrarily low level, it does not mat-
ter 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

\[
I_4 = z_0^4 \\
I_3 = 7z_0^3 - 7z_0^3 \\
I_2 = 21z_0^2 - 35z_0^3 + 14z_0^4 \\
I_1 = 35z_0^4 - 70z_0^5 + 42z_0^3 - 7z_0^6.
\]

Letting \( z_0 \) assume the value unity, all the \( I_4 \)'s vanish 
except \( I_4 \), which becomes unity, so that the pattern is pro-
portional 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 
\( I_4 \).

\[
I_4/I_4 = 1 \\
I_3/I_4 = 7 - 7/z_0^2 \\
I_2/I_4 = 21 - 35/z_0^2 + 14/z_0^3 \\
I_1/I_4 = 35 - 70/z_0^2 + 42/z_0^3 - 7/z_0^4.
\]

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 \( \cos (7u) \) and 
contains no side lobes whenever \( u \) is restricted to the 
range \( 0 \leq u \leq (\pi/2) \). 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 con-
venient 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

\[
G_7(x) = 32I_6x^6 + (8I_1 - 48I_3)x^4
+ (2I_1 - 8I_2 + 18I_3)x^2 + (I_0 - I_1 + I_2 - I_3),
\]

since

\[
cos 2u = 2x^2 - 1 \\
\cos 4u = 8x^4 - 8x^2 + 1 \\
\cos 6u = 32x^6 - 48x^4 + 18x^2 - 1.
\]

Similarly, if \( \phi = \arccos z \)

\[
T_7(z) = 32z^6 - 48z^4 + 18z^2 - 1; \\
- \infty \leq z \leq \infty \\
= \cos 6\phi; \\
-1 \leq z \leq 1
\]

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

\[
I_4 = z_0^6 \\
I_3 = 6I_3 - 6z_0^4 \\
I_2 = 4I_2 - 9I_3 + 9z_0^2 \\
I_1 = I_4 - I_2 + I_3 - 1.
\]

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 \( n = 1, \ldots, 12 \).

Appendix II gives the formula for \( G_0(x) \) 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

$$G = \frac{\left( \sum_{k=1}^{N} I_k \right)^2}{N \left( \sum_{k=1}^{N} I_k^2 \right)}$$

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

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

The first null of this is therefore given by

$$\sin \frac{2Nu}{u} = 0,$$

or $$u = \pi/2N.$$ 

The corresponding first null for a Tchebyscheff distribution is given by

$$u = \arccos \left( \frac{1}{2N - 1} \right)$$

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 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 $\alpha_p$, $\beta_q$ 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

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

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 $\alpha_p$'s, $\beta_q$'s, respectively, equal to zero and to impose the conditions that

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

or that

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

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

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

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

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

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 \(A_p B_q e^{i(\alpha_p \theta + \beta_q \phi)}\) 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

\[
A_0 = 0 \quad B_0 = 0 \\
A_{2p} = 0 \quad B_{2q} = 0 \quad p = 1, 2, \ldots, M \\
q = 1, 2, \ldots, N
\]

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

\[
S_j = \left| \sum_{p=1}^{M} A_p \cos (2p - 1)w \right|.
\]

This is recognized as of the same form as (4) so that the curves contained in the appendixes are applicable. \(S_j\) 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 \(\pm 10\%\) 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

\[
\cos (2n - 1)\theta, \quad n = 1, 2, \ldots, 10
\]

\[
\cos \theta = x
\]

\[
\cos 3\theta = x |4x^2 - 3|
\]

\[
\cos 5\theta = x |16x^4 - 20x^2 + 5|
\]

\[
\cos 7\theta = x |64x^6 - 112x^4 + 56x^2 - 7|
\]

\[
\cos 9\theta = x |256x^8 - 576x^6 + 432x^4 - 120x^2 + 9|
\]

\[
\cos 11\theta = x |1024x^{10} - 2816x^8 + 2816x^6 - 1232x^4 + 220x^2 - 11|
\]

\[
\cos 13\theta = x |4096x^{12} - 13312x^{10} + 16640x^8 - 9984x^6 + 2912x^4 - 364x^2 + 13|
\]

\[
\cos 15\theta = x |16\cdot384x^{14} - 61\cdot440x^{12} + 92\cdot160x^{10} - 70\cdot400x^8 + 28\cdot800x^6 - 604\cdot8x^4 + 560x^2 - 15|
\]

\[
\cos 17\theta = x |65\cdot536x^{16} - 278\cdot528x^{14} + 487\cdot424x^{12} - 452\cdot608x^{10} + 129\cdot360x^8 - 71\cdot808x^6 + 11\cdot424x^4 - 816x^2 + 17|
\]

\[
\cos 19\theta = x |262\cdot144x^{18} - 1\cdot245\cdot184x^{16} + 2\cdot490\cdot368x^{14} - 2\cdot723\cdot840x^{12} + 1\cdot770\cdot496x^{10} - 695\cdot552x^8 + 160\cdot512x^6 - 20\cdot064x^4 + 11\cdot40x^2 - 19|
\]

\[
\cos 21\theta = x |1\cdot048\cdot576x^{20} - 5\cdot505\cdot024x^{18} + 12\cdot386\cdot304x^{16} - 15\cdot597\cdot568x^{14} + 12\cdot042\cdot240x^{12} - 5\cdot870\cdot592x^{10} + 1\cdot793\cdot792x^8 - 329\cdot472x^6 + 33\cdot264x^4 - 1540x^2 + 21|
\]

\[
\cos 23\theta = x |4\cdot194\cdot304x^{22} - 2\cdot411\cdot724x^{20} + 60\cdot293\cdot120x^{18} - 85\cdot917\cdot696x^{16} + 76\cdot873\cdot728x^{14} - 44\cdot843\cdot008x^{12} + 17\cdot145\cdot856x^{10} - 4\cdot209\cdot920x^8 + 631\cdot488x^6 - 52\cdot624x^4 + 2024x^2 - 23|
\]

Check:

If \(x = 1\), \(\cos n\theta = 1\).

**Appendix II**

24-ELEMENT ARRAY

\[
G_{24}(x) = x \left[ 4\cdot194\cdot304x^{22} + (-2\cdot411\cdot724x^{20} + 60\cdot293\cdot120x^{18} - 85\cdot917\cdot696x^{16} + 76\cdot873\cdot728x^{14} - 44\cdot843\cdot008x^{12} + 17\cdot145\cdot856x^{10} - 4\cdot209\cdot920x^8 + 631\cdot488x^6 - 52\cdot624x^4 + 2024x^2 - 23) \times x^{24} \right]
\]
\begin{align*}
+ (-4,209,920I_{12} + 1,793,792I_{11} - 695,552I_{10} \\
+ 239,360I_9 - 70,400I_8 + 16,640I_7 - 2816I_6 \\
+ 256I_5 + (631,488I_{12} - 329,472I_{11} - 695,552I_{10} \\
+ 239,360I_9 - 70,400I_8 + 16,640I_7 - 2816I_6 \\
+ 2816I_5 - 576I_4 + 64I_3)x^3 + (-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{align*}

Check:

\[ G_{23}(1) = I_1 + I_2 + I_3 + I_4 + I_5 + I_6 + I_7 + I_8 + I_9 \\
+ I_{10} + I_{11} + I_{12}. \]

**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**

\[ I_8 = z_0^{12} \]

\[ I_7 = 11(I_6 - z_0^6) \]

\[ I_6 = 9I_6 - 44I_6 + 44z_0^7 \]

**16-Element Array**

\[ I_8 = z_0^{16} \]

\[ I_7 = 15I_6 - 15z_0^{13} \]

\[ I_6 = 13I_7 - 90I_5 + 90z_0^{11} \]

\[ I_5 = 11I_6 - 65I_7 + 275I_5 - 275z_0^9 \]
Fig. 10—The side-lobe level in decibels for "the optimum current distribution" as a function of the scale-contraction factor $\xi_0$ for a 20-element array.

Fig. 11—The side-lobe level in decibels for "the optimum current distribution" as a function of the scale-contraction factor $\xi_0$ for a 24-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. 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.

\[ I_4 = 9I_9 - 44I_6 + 156I_7 - 450I_8 + 450\alpha^2 \]
\[ I_5 = 7I_4 - 27I_6 + 77I_7 - 182I_8 + 378I_9 - 378\alpha^3 \]
\[ I_6 = 5I_3 - 14I_4 + 30I_5 - 55I_6 + 9I_7 - 140I_8 + 140\alpha^3 \]
\[ I_1 = 3I_2 - 5I_3 + 7I_4 - 9I_5 + 11I_6 - 13I_7 + 15I_8 - 15\alpha^3 \]
High-Impedance Cable*

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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 Zo 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

\[ Z_0 = \sqrt{\frac{L}{C}} \text{(ohms, henries, farads).} \]

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.
A few short samples were made and one continuous piece of cable 24 feet in length. Its total capacitance $C$ was 365 micromicofarads, 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.](image)

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

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

follows equation (3)

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

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.

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. 2—Dimensions of experimental cable.](image)

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

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

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

$$T = 10^n \sqrt{\frac{24 \times 10^{-21} \pi^2 n^2 d^2 k}{\log_{10} a/b}} = 10^n \pi dn \sqrt{2.4k} \log_{10} a/b. \quad (7)$$

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

---

conductor is assumed to be a cylinder of the diameter \( b \), then
\[
b = d - w
\]
and the core diameter is, evidently,
\[
c = d - w.
\]

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 Finch 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 \( 1/\sqrt{k} \).

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 \( a/d = \sqrt{\varepsilon} = 1.65 \); thus, for \( a = 0.308 \) inch, \( d = 0.187 \) and \( c \approx 0.45 \) centimeter.

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 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 receivers¹,² 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 frequency-modulation receiver limiters," Electronics, vol. 17, pp. 108-112; August, 1944.


June, 1946

Proceedings of the I.R.E. and Waves and Electrons
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.](image)

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:
- $\omega_0$ = free-running frequency
- $\omega_i$ = frequency of impressed signal
- $\Delta \omega = \omega_0 - \omega_i$ = "undisturbed" beat frequency
- $\omega$ = instantaneous frequency of oscillation
- $\Delta \omega = \omega - \omega_i$ = instantaneous beat frequency.

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

If the oscillator were undisturbed, the only frequencies present would be $\omega_0$ and $\omega_i$, producing a beat frequency $\Delta \omega$. Actually, a lower beat frequency is observed, so that the value of $\omega$ averaged over one complete beat cycle is shifted toward $\omega_i$. We cannot yet predict, however, how large the excursions of the momentary value of $\omega$ might be. We may think of $\omega$ 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 $\omega$ 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 $\omega$ 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

$$\frac{\omega_0}{2Q} \gg \Delta \omega.$$  (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 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 $C_F$ and $R_F$ 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
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.\(^\text{11}\) (For the circuit of Fig. 1 this time constant would be of the order $T = CR_T$.) Since the shortest possible beat cycle corresponds to the "undisturbed" beat frequency $\Delta \omega_0$, we can write

$$T \ll \frac{1}{\Delta \omega_0} \tag{2}$$

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\(^\text{12}\) 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 $\omega_0$ will then produce a large near-resonant amplitude, increasing further the closer $\omega$ approaches $\omega_0$. This amplified signal of frequency $\omega_0$, superimposed on the original signal of frequency $\omega_0$, 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\(^\text{11}\)

$$T' \ll \frac{1}{\Delta \omega_0} \tag{1a}$$

For a simple tuned circuit, $T' = (2Q/\omega_0)$ hence $(\omega/2Q) \Delta \omega_0$ 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

$$E_1 \ll E \tag{3}$$

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 $\omega_0$, that of the external signal, and a vector rotating clockwise with an angular velocity $(d\alpha/dt)$ shall represent an angular frequency $\omega_0 + (d\alpha/dt)$, or angular beat frequency of

$$\Delta \omega = \frac{d\alpha}{dt} \tag{4}$$

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, $E_0$ and $E$ must coincide: the voltage $E$ returned through the feedback

\(^{11}\) For synchronization on a subharmonic of the impressed signal, nonlinearity of the "instantaneous" type is necessary.

\(^{12}\) 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 $\omega_0$. At any other frequency the plate load would introduce phase shift between $E$ and $E_g$. 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.

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 $\phi$.

No such lag could be produced if the oscillator were still operating at its free frequency $\omega_0$. We conclude that the frequency at this instant exceeds $\omega_0$ by an amount which will produce a lag equal to $\phi$ in the plate circuit.

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

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

(5)

The instantaneous frequency $\omega$ 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 $\phi$ versus $\omega$ curve which approaches a straight line with the slope

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

Then, if $\omega_0$ is the free frequency, the phase angle for another frequency $\omega$ close to it will be

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

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

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

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

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

we obtain

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

Adding the impressed frequency $\omega_1$ on both sides, we may also write

$$\omega = -B \sin \alpha + \omega_1.  \tag{9c}$$

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

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

Hence, substituting into (6)

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

and

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

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

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

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
\[ \frac{\omega_0}{\omega_0} \left| \frac{E}{E_1} \right| < 1 \] (13a)
or
\[ \frac{E_1}{E} > 2Q \frac{\Delta \omega_0}{\omega_0} . \] (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 $g_m$,
\[ E_p = E \cdot g_m \cdot Q \sqrt{\frac{L}{C}} . \]

Combining this with (13b), we obtain
\[ \frac{E_p}{E_1} < \left| \frac{\omega_0}{2\Delta \omega_0} \cdot g_m \sqrt{\frac{L}{C}} . \] (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
\[ \frac{E_1}{E} > |A\Delta \omega_0| \] (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
\[ \frac{d\alpha}{dt} = - B \sin \alpha \] (14a)
shows what happens when the external signal $E_t$ is suddenly switched on with an initial lag $\alpha_t$ behind the free-running oscillator. Equation (14a) is quite similar to
\[ \frac{d\alpha}{dt} = - B\alpha \] (14b)
and actually goes over into this form when $\alpha$ is small. Equation (14b) has the familiar solution
\[ \alpha = \alpha_0 e^{-Bt} \] (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 $\alpha_\infty$ 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 $\alpha$ as a function of time, it is necessary to integrate (9b). We first substitute
\[ K = \frac{\Delta \omega_0}{B} \] (15a)
which means for a single tuned circuit
\[ K = 2Q \frac{E}{E_1} \frac{\Delta \omega_0}{\omega_0} . \] (15b)

By comparing with (13a) and (13d), we find that the condition for synchronization can now be written
\[ |K| < 1. \] (15c)
Substituting into (9b) we obtain
\[ \frac{d\alpha}{dt} = - B(\sin \alpha - K). \] (16)
Integration gives
\[ \frac{\alpha}{2} = \frac{1}{K} \sqrt{K^2 - 1} - \frac{B(t - t_0)}{K} \tan \frac{1}{2} \sqrt{K^2 - 1} + \tan \left[ \frac{1}{K} \sqrt{K^2 - 1} \tan \frac{B(t - t_0)}{K} \right] \] (17a)
or
\[ \alpha = 2\tan^{-1}\left[ \frac{1}{K} \sqrt{K^2 - 1} \tan \frac{B(t - t_0)}{K} \right] \] (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 $\pi/2, 3\pi/2, \ldots$, and the tangent on the right side of (17a) will become $+\infty, -\infty, \ldots$ in succession; at these instants $\alpha/2$ must also be $\pi/2, 3\pi/2, \ldots$, 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 \( 2\pi \) seconds—is therefore

\[
\overline{\Delta \omega} = B \sqrt{K^2-1}
\]  

(18a)
or, substituting from (15a),

\[
\overline{\Delta \omega} = \Delta \omega_0 \frac{\sqrt{K^2-1}}{K}.
\]  

(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](image)

**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 \( \Delta \omega_{\text{max}} \) for which locking can occur (\( K=1 \) for \( B=\Delta \omega_0 \)). So the instantaneous beat frequency \( \Delta \omega \) will vary periodically between \( \Delta \omega_0 - \Delta \omega_{\text{max}} \) and \( \Delta \omega_0 + \Delta \omega_{\text{max}} \) as long as \( \Delta \omega_0 \) exceeds \( \Delta \omega_{\text{max}} \).

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

\[
\Delta \omega_{\text{max}} = \frac{\omega_0}{2Q} \frac{E_1}{E}
\]  

(19a)
or

\[
\Delta \omega_{\text{max}} = \frac{\omega_0}{2} \frac{E_1}{E_p} \frac{L}{C}
\]  

(19b)

for a single-tuned circuit, and

\[
\Delta \omega_{\text{max}} = \frac{1}{A} \frac{E_1}{E}
\]  

(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

\[
y \cos \alpha(t)
\]

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 \( \alpha \) on the way to the detector. Fig. 6 shows an example with a phase shift of \( \pi/2 \):

![Fig. 5](image)

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

![Fig. 6](image)

**Fig. 6**—Wave form of beat note for \( \cos \left[ \alpha(t)+\pi/2 \right] \).

function plotted is \( \cos \left[ \alpha(t)+\pi/2 \right] \) 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 \( j\sqrt{1-K^2} \). By use of the relation \( \tanh x = -j \tan jx \), equation (17a) is transformed into

\[
\tan \frac{\alpha}{2} = \frac{1}{K} \frac{\sqrt{1-K^2}}{\sqrt{1+K^2}} \frac{B(t-t_0)}{2} - \sqrt{1-K^2},
\]

(20a)

The integration constant \( t_0 \) permits one to fit the equation to the initial phase difference \( \alpha_0 \), which exists when the external signal is switched on.

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

\[
\tan \frac{\alpha}{2} = \frac{1}{K} \frac{\sqrt{1-K^2}}{\sqrt{1+K^2}} \frac{B(t-t_0)}{2} - \sqrt{1-K^2}.
\]

(20b)

Using (16) we identify \( K \) with \( \sin \alpha_0 \) for the steady state. Hence \( \sqrt{1-K^2} \cos \alpha_0 \), and (20b) becomes \((1-\cos \alpha_0)/\sin \alpha_0 \), which is indeed equal to \( \tan \left( \alpha_0/2 \right) \) by a trigonometrical identity.

**VII. A Mechanical Model**

In conclusion, let us construct a mechanical model to

Equation (20a) holds for \( \sin \alpha_0 > k \). 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 \(\alpha\) 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.](image)

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 \(\alpha_0\) 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 \(\alpha_1 = \pi - \alpha_0\), 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 \(\Delta \omega_{\text{max}} = B\) 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 \(\Delta \omega\) 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, 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.
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'Arsenval) 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.

Consider the basic circuit of Fig. 1.

Let $E_1$ = true voltage between terminals $A$ and $B$ with the voltmeter disconnected

$E_2$ = voltage measured on the highest range that will give an accurate reading

$E_2$ = voltage measured on the next range lower than used for $E_1$

$E_2$ = 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 $E_1$, $E_2$, and $E_3$. Simple circuit theory allows us to write

$$E = E_2 - \frac{R_n}{R_m + R_n}$$

then

$$E_1 = E_2 - \frac{R_n}{R_m + R_n} + \frac{R_n R_m}{R_m + R_n}$$

or

$$E_1 = E_2 - \frac{R_n}{R_m + R_n} + \frac{R_n R_m}{R_m + R_n} + \frac{R_n R_m}{R_m + R_n}$$

$$E_2 = E_2 - \frac{R_n}{R_m + R_n} + \frac{R_n R_m}{R_m + R_n}$$

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

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

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

Rearranging (3) and (4),

$$(R_n + R_1)(E - E_1) = E_1 - \frac{R_n R_m}{S R_1}$$

$$(R_n + R_1)(E - E_2) = E_2 - \frac{R_n R_m}{R_m}$$

Dividing (5) by (6),

$$S E_2 (E - E_1) = S E_1 (E - E_2)$$

Thus,

$$E = \frac{S - (E_1/E_2) - 1}{S - (E_1/E_2)}$$

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 cathode 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). Let $I_1$ = actual current that flows in the absence of the ammeter

$I_2$ = current measured on the highest range that will give an accurate reading

$I_3$ = current measured on the next range lower than used for $I_1$

$E_a$ = 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 $I_3$

$R_c$ = circuit resistance

$S$ = ratio of the two scales used ($S = R_1/R_2$) (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

$$I_1 = \frac{E}{R}$$

also

$$I_1 = I (\frac{1}{1 + R_1/R})$$

and

$$I_2 = I (\frac{1}{1 + R_1/R})$$

Substituting $S R_1$ for $R_1$ in (9) and solving for $R$ in both equations,

$$R = \frac{R_1 I_1}{I - I_1}$$

Solving for $I_1$, we have

$$I_1 = \frac{S (R - 1) I_1}{S - (R - 1) I_1}$$

**RAYMOND E. LAFFERTY**

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Contributors to Proceedings of the I.R.E.

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.

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 magnetostriuctive oscillators. More recently, he was active in the vacuum-tube field through his development of the phasitron system of frequency modulation.

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 Industries, 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.

June, 1946

Proceedings of the I.R.E. and Waves and Electrons
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.

**A GROUP OF NOTABLES**

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
CLEDI 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.

The members of the various committees responsible for the conference are given below.

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1946
Proceedings of the I.R.E. and Waves and Electrons 361
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.

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.

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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 11” 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 president of ARRL, accepted 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 (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.
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."

DR. LLEWELLYN ATTENDS CONVENTION IN LONDON

At the invitation of the Institution of Electrical Engineers, Dr. F. B. Llewellyn, president of the Institute of Radiologists, 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.

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.
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 Barkhausen 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

(Continued on page 365)
I.R.E. People

CLINTON B. DE SOTO

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.

(Continued from page 364)

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.

(Continued from page 364)
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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
National Research Council, Division of Engineering and Research: F. E. Terman
Radio Technical Planning Board: W. L. Barrow (D. B. Sinclair, alternate)
U. S. National Committee, Advisers on Electrical Measuring Instruments: Mobile Eastham and H. L. Olsen
U. S. National Committee, Advisers on Symbols: L. E. Whittemore and J. W. Horton

* 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.
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.
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 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-aford 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 cot-ond, 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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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 grid-iron 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 will 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 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 establishment 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.

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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.

Reference is made to the block diagram, Fig. 3, where

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.

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\(\frac{1}{2}\) 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
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. 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.

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.
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.

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.

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 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 particu-
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 worthwhile technical data to this paper.

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.

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” (pilot-less 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.

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. 15—100-megacycle television camera-transmitter suspended under General Motors Bug.

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. 16—General Motors Bug being taxied by radio control from B-23 airplane at Muroc Lake, California.

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 kind 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.

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 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.

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.

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 ripples. 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.

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 reinforced 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.

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. 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.

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...
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.

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.

![Diagram of dynamotor showing four output sections on one shaft.](image)

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.

![Radio receiving equipment SCR-550-T3.](image)

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.

![Diagram of dynamotor showing four output sections on one shaft.](image)

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.

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.

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 trans-

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**Fig. 34**—Monitor unit BC-1214-T3.

**Fig. 35**—Functional block diagram of monitor unit used with camera and receiver.
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 disturbed, 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 1-231 and the 1-232 (see Figs. 37 and 38).

![Experimental test bench with 100-megacycle camera-transmitter in place. The test pattern was placed on the vertical support facing the projector lamps.](image)

The 1-231 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.
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 1-232 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 8½-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.

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.

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.

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.

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.

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

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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.

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 intermittent 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 airframe, 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 of glide bomb shows a wide bars due to microphonics of about 200 cycles per second. Target information is completely obscured.

Fig. 48—Television picture from glide bomb shows a 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 in GB-4 and smaller bars due to microphonics of approximately 3000 cycles per second.

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. 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. 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. 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 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.

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

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.
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.

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.

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.

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.

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 identi-

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**Fig. 59—Target area, Tonopah, Nevada, on television-receiver screen.**

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...cal 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.

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.](image1)

![Fig. 62—Receiver installed in radio compartment of B-17 airplane. The television operator monitors synchronizing, contrast, and carrier controls.](image2)

![Fig. 63—B-17 airplane carrying two GB-4 glide bombs on tactical mission over Europe.](image3)

![Fig. 64—GB-4 glide bomb just after drop away from B-17 airplane.](image4)
ground surface can be expressed as follows:

\[ \tan \alpha = \sqrt{\frac{(h_1 + h_2)^2}{d^2} - \frac{(h_1 - h_2)^2}{d^2}}. \]

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 \(\alpha\) 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 \(\alpha\) 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 \(\alpha\) 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.

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.

Fig. 66—Geometrical relationship between direct and reflected wave.
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.

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*
KEATS A. PULLEN, JR.,†, MEMBER, I.R.E.

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" have made an excellent begin-
ing 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 experimen-
ting 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-fol-
lower 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 hav-
ing 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 conduct-
ance. 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 mega-
cycles, then the maximum impedance in the plate circuit
will be the product of circuit Q multiplied by the ca-
pacitive reactance; namely, 800 times 50, or 40,000
ohms. As a grounded-grid amplifier, the effective am-
plication is reduced by 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 accom-
plished with a voltage loss of approximately 2 to 3.

III. THE MULTIVIBRATOR

This circuit also makes a unique type of multivibra-
tor. 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 conduct-
ing 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 genera-
tor. 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 will make the block multivibrator
have a unique characteristic. This unit will trip over once for each
positive or negative pulse. A direct-current microam-
pmeter 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.

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† The Pullen Laboratories, Brooklyn, N. Y.
† G. C. Sziklai and A. C. Schroeder, "Cathode-coupled wide-band

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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 fre-
quency-determination circuit, only two resistors are re-
quired to make the unit.
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.

V. RADIO-FREQUENCY OSCILLATORS

There are several methods of making the circuit into an oscillator in addition to the one noted in the literature. 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 microfarads, 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.

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

![Fig. 4—The shunt-circuit oscillator.](image)

![Fig. 5—The series-circuit oscillator.](image)

![Fig. 6—The resonant-resistance meter.](image)
ay. For this experiment, the total tube input capacitance.

A multivibrator, the same design is interesting to note that a single

(Fig. 9). Taking the input voltage as $e_i$, the input current as $i_0$, 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:

$$e_i = i_0Z_i + Z_k(i_1 + i_2).$$

Taking the plate load impedance as $Z_k$, the plate resistance as $R_p$, and the tube amplification factor as $\mu$, the second equation is

$$[(i_1 + i_2)Z_k] = i_2Z_k + R_p + Z_k + i_0Z_k.$$

Solving these two for the voltage gain, which is $i_2Z_k/e_i$, the effective amplification is

$$e_0/e_i = \mu Z_k/[Z_k(1 + \mu) + (Z_k/Z_k + 1)(R_p + Z_k)].$$

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 $\mu$. Setting up the plate-current loop, remembering the voltage on the grid is the difference between $e$ and $i_pZ_k$, the plate current becomes

$$i_p = e\mu/[((1 + \mu)Z_k + R_p].$$

Then subtracting voltage output from input gives circuit loss. This gives

$$e_{loss} = (Z_k + R_p)e_i/[Z_k(1 + \mu) + R_p]$$

as the voltage lost across a hypothetic series dropping resistance. Dividing this by $i_p$ gives the expression

$$loss\ impedance = (Z_k + R_p)/\mu = Z_k/\mu + 1/g_m.$$
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 electroacoustic 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 electroacoustics 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.

Leonard 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.

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.

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.

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 Materiel Command, at Wright Field.

Charles J. Marshall

E. Finley Carter
### Abstracts and References


The number at the upper left of each Abstract is its Universal Decimal Classification number and is not to be confused with the Decimal Classification used by the United States National Bureau of Standards. The number in heavy type at the top right is the serial number of the Abstract.

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Mr. George W. Bailey Executive Secretary The Institute of Radio Engineers, Inc. 330 West 42nd Street New York 18, N. Y.

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<tr>
<td>513.4</td>
<td>621.896 619.018.41</td>
<td>1114</td>
<td>Push-Pull Frequency Modulated Circuit and Its Application to Vibratory Systems—A. Budmaier. (Jour. Soc. Mot. Pic. 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 (Rois).</td>
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<td>534.321.9: 538.652</td>
<td>1117</td>
<td>Magnetostriuctive Oscillator Coupling—H. Thiele. (Elec. Ind., vol. 5, p. 96; January, 1946.) A piston coupler of ceramic allows the application of a magnetostriective oscillator under circumstances beyond its normal 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.</td>
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<td>534.321.9: 620.179</td>
<td>1118</td>
<td>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. Pulsers, 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).</td>
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<td>534.321.9: 620.179</td>
<td>1119</td>
<td>Ultrasonic Vibrations Revealed 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 microphome 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.</td>
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<td>534.41</td>
<td>1121</td>
<td>Electronic Sound Effects Circuit—H. Syzing. (Electronics, vol. 19, pp. 214-220; January, 1946.) Description of a battlesound 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.</td>
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<td>534.43: 621.305.61</td>
<td>1123</td>
<td>New Vibrating Reed Magnetic Pickup—R. B. 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.</td>
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<td>534.43: 621.305.61</td>
<td>1124</td>
<td>[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.</td>
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<td>534.845: 534.373</td>
<td>1125</td>
<td>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.</td>
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The Solution of Transmission-Line Problems—C. G. Aurell. (Eriksen 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.

Aerials and Transmission Lines

621.392

The Solution of Transmission-Line Problems in the Case of Attenuating Transmission Line—G. Glinski. (Trans. A.I.E.E., Feb., 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

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

Minimum Attenuation in Waveguides—E. N. Phillips. (Electronics, vol. 19, pp. 137-139; January, 1946.) Vehicular 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_m) to the cutoff 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_m = f_c \times \sqrt{n^2 + m^2}. The attenuation of an H_01 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

Aerial Resistance and Cable Impedance—W. 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; 621.396.62

Radio-Frequency Resistors as Uniform Transmission Lines—D. R. Crosley and C. H. Penney. (Proc. I.R.E. and Waves and Electrons, vol. 34, pp. 621-661; February, 1946.) A theoretical analysis, using the classical transmission-line equations, of concentric lines with resistive inner conductors, the resistive 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; 621.396.43

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 one 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  

621.396.67

1180  
Three New Antenna Types and Their Applications—A. G. Kambian (Proc. I.R.E. and Waves and Electronics, vol. 1, pp. 70M-75M; 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 substantially omnidirectional in applications 621.396.67.

621.385.2/5012.8  
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 all-important circuit by attaching a definite sign to both current and voltage symbols. Comment on 3569 of 1945 (G.W.O.H.).

621.392.5  
1188  
Translent Response of Filters [Part II]—D. G. Tucker. (Wireless Eng., vol. 23, pp. 84-90; March, 1946.) The method given in part 1 (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/.3976  
1189  
Cathode-Follower Dangers: Output Circuit Capacitance—W. T. Glocking. (Wireless World, vol. 34, pp. 71P-77P; February, 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 radio 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. The far 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.

621.318.572: 621.385.38  
1186  
Pulse Response of Thyratron Grid-Control Circuits—C. H. Gleason and C. Beckman. (Proc. I.R.E. and Waves and Electronics, vol. 34, pp. 71P-77P; February, 1946.) Advantages of peaked-waveform grid signals are discussed, and graphs given from which influence of grid-circuit components on the grid-potential waveform 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 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.

621.394/.3976  
1191  
Noise Factor of Valve Amplifiers—N. K. Campbell, V. J. Francis, and E. G. Janes. (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 factor of a single-tube stage are derived to derive particular formulas for the common-grid triode and the common-cathode pentode, account being taken of load impedances and interelectrode capacitances. Properties of perfect and dissipative four-terminal 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/.3976  
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/.3976  
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/.3976  
1194  
Phase-Inverter Circuit—C. B. Fisher and D. L. Drucke. (Proc. I.R.E. and Waves and Electronics, vol. 34, pp. 92P; February, 1946.) An application of the circuit described by Drucke (3846 of 1945) A multiple explanation of the phase-inverter circuit, described by Drucke (3846 of 1945) for the elimination 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/.3976  
1195  
An Analysis of Three Self-Balancing Phase Inverters—M. S. Wheeler. (Proc. I.R.E. and Waves and Electronics, 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.

621.395.14: 621.395.645  
1196  
Carrier-Frequency Amplifiers: Transient Response with De-tuned Carrier—C. C.
Proceedings of the I.R.E. and Waves and Electrons

June

Eaglesfield. (Wireless Eng., vol. 23, pp. 67-74; December, 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).

621.395.645.3


621.395.645.5

A Study of the Comparison of Beam Power and Triode Tubes Used in Power Amplifiers for Driving Loudspeakers—Hilliard. (See 1166.)

621.396.61

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 to set the 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.

621.396.645.36

Quality Amplifiers—(Wireless World, vol. 52, p. 61; February, 1946.) Correction to a circuit in 838 of April.

621.396.665

Mixing Crystal Microphones—Patchett. (See 1169.)

621.396.82


621.396.611.1


621.396.615.4

1200

A New Type of Electrical Resistance—E. E. Schneider. (Phil. Mag., vol. 56, pp. 371-392; June, 1945.) Utilization of phase inversion in a vacuum tube leads to a method of obtaining resistance with circuits containing only resistance and capacitance or resistance and inductance. Such circuits are compared with the 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

1209

Asymmetrical Butterfly Circuit—A. Landman. (Proc. I.R.E. AND WAVES AND ELECTRONS, vol. 34, pp. 929; 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 (Kaprul) and 1209.

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-Muller tube circuits, accurate synchronization between a pulse generator and a cathode-ray tube 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 cathode-ray tube. The assembly is followed by a differentiator and flip-flop circuit and its application to vibratory systems—Badmaeffi. (See 1144.)

621.396.66

Control and Recording with Floating Grid—E. L. Deeter. (Electronics, vol. 19, pp. 172-178; January, 1946.) A large alternating voltage is applied through a very small capacitance (about 0.2 microfarad) 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

Electronics for Engineers [Book Review]—Markus and Zeluff. (See 1428.)

621.392: 621.3.015.33


GENERAL PHYSICS

530.12: 531.18

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


531.4+539.62+621.394.653+621.395.653

comprehensive review of experimental information on the mechanism of frictional forces. The area of true contact is only a very small fraction (about $10^{-6}$) 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 the 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 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

The Wave Equation in a Medium With a Variable 

535.317: 621. 397

[Optical] Lens Aberrations in Picture Projection—Montani. (See 1379.)

535.43

On the Theory of Light-Scattering—A Note—S. Parthaasrathy. (Phil. Mag., vol. 36, pp. 510-514; July, 1945.) A continuation of an argument with Krishnan (see 334 of 1940). The writer claims that Krishnan's results "have been vitiated by grave errors" and gives detailed reasons.

537.221: 621.317.

A Modified Kelvin Method for Measuring Contact Potential Differences—Meyerhof and Miller. (See 1282.)

537.525

Small Perturbations of the Electric Discharge—V. L. Granovski, (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—Granovski) describing the dynamic states of the plasma under 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 damped, and various semiquantitative conclusions reached on the relationship between the modulating electromotive force and the current, particle concentration, etc.

537.541(001)

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


538.1

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.

538.60, 61: 621.396.11.029.64

The Absorption of Microwaves by Gases—Hershberger. (See 1336.)

539.16, 08

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 $\beta$ decay of currents in the core are calculated for the factor of the lawson and Tyler spectrometer.

539.16, 08: 621.38, 55

Use of 6AK5 and 954 Tubes in Ionization Chamber Pulse Amplifiers—Parsegian. (See 1404.)

539.163, 20

The Theory of the 180° Magnetic Focusing 

621.38, 833

Space-Charge-Limited Beams in Electrostatic Fields—Rose. (See 1313.)

5 223


530.145.6

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 of the reader, and also in that it deals only with the elements of wave mechanics."
What Are Fireballs?—E. A. Logan. (Elec. Ind., vol. 4, pp. 621.396.9
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

Photoelectric Aid for the Blind—(See 1309.)

621.306.82: 621.386.9

Radar Countermeasures—D. G. F. (See 1240.

621.306: 621.9 +.94

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 detectable 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."

621.306.9

Deca 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 Deca system uses continuous waves and can therefore take advantage of the more favorable ground-wave propagation characteristics of frequencies and the order of 100 kilocycles per second. For two synchronized transmitters, the location of receiving points associated with given constant-phase differences are a family of hyperbolae. A third synchronized transmitter similarly determines another family of hyperbolae, and the ship may be located on the intersection of two hyperbolae by observations of the phase differences between the received signals. This is the essential theoretical basis of the Deca system. In practice, the master transmitter controls two remote phase-locked slave transmitters. The return of the transmitted pulse between two transmitters 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 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.

621.306.9

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.).

621.306.9

The Future of Radar—L. A. DuBridge. (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.

621.306.9


621.306.9

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 cabin and two in remote positions convenient for navigation. Operating frequency evidently about 10,000 megacycles per second.

621.306.9

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 used 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."

621.306.9

1248


621.306.9

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-4. 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 symbol is illustrated. There is a-scope and plan-position-indicator display. To be continued.

621.306.9

1250

The [AN/] MPG-1 Radar—H. A. Straus, L. J. Rugeer, C. A. Wirt, 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 radiation comes through a parabolic cylinder as reflector, and produces a beam about 0.6 degree wide and 3 degrees high. The scanning system is described.

621.306.9

1061.6

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 description of the chief activities of the Laboratory and a list of the staff.

621.306.9

1252

Radio Proximity Fuze—Trotter. (See 1326.)

621.306.9

1253

Fundamentals of Radar: S. Beacorns Employed in 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.

621.306.9

1254

Direction Finder—M. Rosson. (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.

621.306.9

1255

Microwave Instrument Blind Landing System—Sperry Gyroscope Co. (Elec. Ind.,
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 pre-determined angle from the board edges, 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


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 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 re-inversion 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 “treatment.” Abstract of an American Physical Society paper.

621.351.6 1266


537.228.1 1267

Radio Insulating Materials: Part IV—A. H. Posluc. (Radio, vol. 29, pp. 33–60; December, 1945.) Preparation and properties of compression-moulded and transfer-moulded glass-lined mica (permittivity 7). Higher permittivity materials (+ up to 20) in moulded forms, and temperature compensating materials having permittivities up to 80 and a temperature capacitance coefficient of 1 in 10° are available. For part 3, see 632 of March.

621.315.61 1268

Electrical Properties of Indian Mica: II. The Effect of Varying Relative Humidity—P. C. Mahanti, M. K. Mukherjee, and P. R. Roy. (Indian Jour. Phys., vol. 19, pp. 83–92; June, 1945.) A continuation of the work described in 543 of 1943 (Datta, Gupta, and Mahanti). The measurement was by substitution of a standard air capacitor in a Sechering 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 sulfate, etc., and 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 means of refractive indices. 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 1269


621.318.22 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 other 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 4 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 Hz 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 II—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.


MATHEMATICS

517.432 1276 The Steady-State Operational Calculus—D. L. Waidelich. (Proc. I.R.E. and Waves and Electrons, vol. 34, pp. 788-838; 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 calculations."

517.9141 1277 Computation of the Solution of Mathieu's Equation—N. W. Mclachlan. (Phil. Mag., vol. 36, pp. 403-414; June, 1945.)


MEASUREMENTS AND TEST GEAR

621.3.0125 1281 Decibel Conversion Chart—R. C. Miekle. (Proc. I.R.E. and Waves and Electrons, vol. 1, pp. 76W-77W, February, 1946.) The chart gives decibels directly from any two of voltage, current, or power, for ratios up to 106 to 1 with an extended range for ratios up to 1010 to 1.

621.3.32 1282 A Modified Kelvin Method for Measuring Contact Potential Differences—W. E. Meyerhofer 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, the pulse is reduced to zero and measures the contact potential difference to 0.01 volt.

621.3.01533 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.

621.3.3820299 1284 Power Measurements at Audio Frequencies—D. L. Waidelich. (Elec. Ind., vol. 5, pp. 68-70; February, 1946.) Describes the threovoltmeter method as given by Laws in his book "Electrical Measurements" (2508 of 1938). A second method, using a network and two theremin cut 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.

621.38739 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.

621.3.1741 + 621.3.2431 + 621.3.0295 1286 Proposed Test Coils—(Elec. Ind., vol. 5, p. 71; January, 1946.) "Testvandes for testing permeability and Q of powdered iron slugs 1 inch in diameter and 1 inch long."

621.3.42 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’Arcysonval 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.

621.3.74 + 621.3.84 + 621.3.69 1288 Physical Society's Exhibition: First Postwar Show of Testing and Measuring Gear—(Wireless World, vol. 52, pp. 48-52; February, 1946.) See also 1131/1133 of April.

621.3.7 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, voltimeters, frequency meters, alternating-current bridges, oscillators, signal generators, and a new alternating-current—direct-current comparator. See also 1131/1133 of April.

621.3.71 : 621.3.9667 1290 Remote Indicating Antenna Ammeter—C. R. Cov. (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.

621.3.734 1291 A Simple Ohmmeter—"Calibrator." (Wireless World, vol. 52, p. 44; February, 1946.) Brief description of a circuit in which a single voltmeter is used alternately for measuring the current through and the potential drop across the unknown resistor. Resistances up to 10 ohms can be measured.

621.3.734 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.
261.317.76: 621.396.621 1203
Laboratory Receiver—W. F. Frankart. (Elec. Ind., vol. 5, pp. 71, 114; 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 amplification and frequency modulation.

261.317.761 + 621.396.611.20 023 1204

261.317.761 029.3 1205
Introduction to U. H. F. Frequency Measurements—G. Dexter. (Radio News, vol. 35, pp. 32-114; January, 1946.) The principles of the 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.

261.317.79: 637.228.1 1206

261.317.79: 621.396.612 1207
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 megacycles 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 with a magnetic-tube per second. A magnetically tuned oscillator is claimed to be "almost foolproof and obscenity-proof."

261.317.79: 621.396.615.14 1208
125 to 500 Megacycle Signal Generator—J. Wonsiewicz 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 a single hand 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.

261.317.79: 621.396.616.2 1209

261.392.43 1300
Shunt and Series Sections of Transmission Line for Impedance Matching—Tai. (See 1178.)

261.315.6(083.75) 1301
ASTM Standards on Electrical Insulating Materials (with related information) [Book Review]—ASTM Committee D-9. (See 1274.)

261.390.83 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.

261.385: 515.33.071 1310

261.384 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.

261.385 1312
Physical Limitations in Electron Ballistics—Pierce. (See 1395.)

261.385.833 1313

261.385.833 1314

261.885.833 1315
Complete Computation of Electron Optical Systems—L. Motz and L. Klafter. (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."

261.885.833 1316

261.885.833 1317
Electron Microscope Society of America


of resonant-frequency 'drifts' in the preselector, intermediate-frequency amplifier, and oscillator-tuning circuits of a superheterodyne-type receiver.

621.396.612.54 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.

621.396.612.59 1344
Discriminating between Signals of Different Amplitude—E. H. Ulrich. (Elect. 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.

621.396.612.59 1345

621.397.8 1346
Television for Urbanized Areas [siting of aerials]—Duval. (See 1384.)

STATIONS AND COMMUNICATIONS SYSTEMS

621.396.619 1347
Phase and Frequency Modulation—F. Green (Marconi Rev., vol. 8, pp. 113–118; October/December, 1945.) Vector diagrams are used to show the relationships 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: 621.485.5 1348
Phasitron Converts from AM to FM Directly—(See 1405.)

621.396.619:018.41 1349
Frequency Modulator—D. A. Bell. (Elect. 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 Technique—(Elect. Ind., vol. 4, pp. 82–100; 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 1054 of April (Cooke) and 183 of January (Roberts and Simmonds).

621.396.619:16 1352

621.396.65.029.62/64 1353
The [U.S.] Army's Radio Relay Equipment—A. R. Boone. (Radio News, vol. 35, pp. 25–25; January, 1945.) The AN/TRC-1 is a frequency-modulation set transmitting at 70 to 100 megacycles per second from a double-H aerial, providing two telephone channels. The AN/TRC-8 is similar but operates at 280 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 paraboloid 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 repeaters, necessary. For descriptions of AN/TRC-5 and AN/TRC-6, see 1058/1056 of April and back references.

621.396.7 1354
The [U.S.] Signal Corps on and in the Air—C. F. Jackson. (Radio News, vol. 35, pp. 94–108; January, 1946.) A complete airborne radio station to meet the specific, 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

621.396.82: 621.9 1356
Radar Countermeasures—J. 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 two heterodyne transmitters having random-noise modulation, or by reflecting foil strips of suitable length (“window” or “chaff”). Wide-band aerial systems and the resonator (a tetrodoid giving 30 kilowatts continuous wave at 500 megacycles per second) are briefly described. The new 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 locations 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
2600-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, transmitter, and power supplies. The 10-watt transmitter uses a crystal-controlled oscillator, its frequency multiplied up to 2600 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 omniumitral 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

621.396.629.13 1360
Aviation Radio [Book Review]—Roberts. (See 1256.)

SUBSIDIARY APPARATUS

539.16.08 1361

621.526 1362

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.) The determination of design criteria 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 \( E_m = 0.6E_{Fmax} \) 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 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. Gurevitsch and P. C. Noble. (Gen. Elect. Rev., vol. 48, pp. 46–52; December, 1945.) The supply was designed for an electron-diffraction instrument. A 35-kilocycle-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-kilocycle-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 megohms, 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-amperes alternator in the appropriate direction. The alternating voltage is regulated to \( \pm 0.02 \) 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. (Elect. 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 disk and simulated the charge as 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. Stobo. (Radio News, vol. 35, pp. 34–114; 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—(Elect. 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 F. E. Charlton. (Elect. Eng., vol. 64, pp. 427–432; December, 1945.) See 270 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. (Elect. Eng., vol. 64, pp. 444–448; December, 1945.)

621.398:2  1373 Industrial Relay Control Circuits—Batcher. (See 1391.)


TELEVISION AND PHOTOTELEGRAPHY

621.383.8  1376 High Sensitivity Pickup—(Elect. 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.)


621.397:621.396.619.1  1380 Amplitude Modulator for Facsimile—Arzt. (See 1390.)


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. 19, No. 6; November, 1945.) 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 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 transmission circuitry."

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 small-
ness. 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

January, 1946.) There is no ready-made solu-
tion for the best siting of television aerials,
which it was based.

621.396.619.1: 621.397.9

1389

Amplitude Modulator for Fasscimile—
M. Artzt. (Elect. Ind., vol. 4, p. 172; De-
cember, 1945.) A method of modulating a
wave from a resistance-capacitance-coupled
oscillator at the maximum possible keying
rate, with freedom from transients. Sum-
mmary of U.S. Patent 2,373,737.

VACUUM TUBES AND THERMIONICS

537,525

Small Perturbations of the Electric Dis-
charge—Granovsky. (See 1224.)

537,533.8

Erratum: Secondary Emission of Pyrex
vol. 17, p. 62; January, 1946.) Correction to
the composition of the glass quoted in
3618 of 1945(Mueller).

621.38(983.72)

1393

The Tron Family—W. C. White. (Elect.
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 Elec-
tron Beam and an Oscillating Electric
Field—J. Marcom. (Jour. Appl. Phys.,
vol. 17, pp. 4-11; January, 1946.) "Relations
between various parameters are obtained
which describe the behavior of an ac-
celerated electron beam which is caused to
traverse an alternating electric field. In
particular, a mechanigraphical means for
obtaining the gain or loss of energy is de-
scribed. 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."
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: 620.63

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 wave barriers. Frequency/power (Ricke) diagrams, and typical operating conditions are given for the 4J36-4J41 type.

621.385: 3.029.5: 621.396.15: 062.69

A Vacuum-Contained Push-Pull Triode Transmitter—Type VT158—H. A. Zaliz, J. E. Gorham, and G. F. Rouse. (Proc. I.R.E. and Waves and Electrons, vol. 1, pp. 609-616; February, 1946.) The rectifying 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 70 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


621.385: 621.396.619

Phasotron Converts from AM to FM Directly—Elec. Ind., vol. 5, pp. 78-79; January, 1946.) For horizontal circular disk of electrons from the cathode of the phasotron are modulated at the crystal-controlled carrier frequency by a grid system that sends 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 feedbacked 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 electron and therefore carries a current alternating at the carrier frequency and phase-modulated at the audio frequency.

621.385.5: 621.396.621.54

Recent Developments in Converter Tubes—W. A. Harris and R. F. Dunn. (Electronics, vol. 19, pp. 200-204; January, 1946.) Description of the OSBY converter which has a conversion transconductance of 0.9 milliamperes 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, pp. 81; December, 1945.

621.385: 621.396: 018: 41

Ratio- Controlled Amplifier—C. W. Han- sell. (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


001: 89

Science and the Government—H. M. Kilgore. (Science, vol. 193, pp. 6-8; January 4, 1946.) 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)

Aliance of Industry and Scientific Research in Great Britain—B. J. A. Barl. (Science, vol. 193, 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.

510: 283,

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.

510: 283,

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

Progress Depends on Sound Engineering—J. A. Slobbe. (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.

621.301: 2: 621.308: 14

Decibel Conversion Chart—Miekk. (See 1281.)

621.308: 64-321: 017: 72

Heat Dissipation from Cabinets for Electrical Instruments—H. C. Littkejohn. (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

A Laboratory for Basic Electronics—P. H. Honnell and W. E. Strohm. (Elec. Eng., vol. 65, pp. 75-80; February, 1946.) 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: 95: 395: 531: 4+539: 62

The Physics of Rubbing Surfaces—Bowden. (See 1219.)

621.396: 107: (058: 7)


621.396: 62: 017: 72

1946 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

1946 History and Activities of the Radiatior Laboratory of the Massachusetts Institute of Technology—DuBridge. (See 1281.)

621.38

To Solar, "CQ" means Capacitor Quality because Solar lives up to its by-word, "Quality Above All."

That's the whole Solar story in one sentence.

We could show pictures of departments in our up-to-the-minute plants, depicting the modern machines and skilled workers who build outstanding quality into each Solar capacitor that comes off the lines. Or photos of our laboratories where tests insure that every Solar capacitor will live up to Solar's "Quality Above All" standards.

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ELECTROLYTIC, PAPER AND MICA CAPACITORS FOR THE ELECTRONIC INDUSTRY

Proceedings of the I.R.E. and Waves and Electrons June, 1946
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

<table>
<thead>
<tr>
<th>Carbonyl Iron Grade</th>
<th>Weight-Average Diameter Microns</th>
<th>Total Fe Content %</th>
<th>Total Carbon Content %</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>20</td>
<td>99.7-99.9</td>
<td>0.005-0.03</td>
</tr>
<tr>
<td>C</td>
<td>10</td>
<td>99.5-99.8</td>
<td>0.03 -0.12</td>
</tr>
<tr>
<td>E</td>
<td>8</td>
<td>97.9-98.3</td>
<td>0.65 -0.80</td>
</tr>
<tr>
<td>TH</td>
<td>5</td>
<td>98.1-98.5</td>
<td>0.5 -0.6</td>
</tr>
<tr>
<td>SF</td>
<td>3</td>
<td>98.0-98.3</td>
<td>0.5 -0.6</td>
</tr>
</tbody>
</table>

**RELATIVE Q VALUES OF THE 5 CARBONYL IRON POWDER GRADES**

- "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**
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.
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...
TYPICAL!
The Shallcross Type 637 Bridge combines both the Kelvin and Wheatstone circuits in a single portable and durable instrument. Provides a resistance measurement range from .001 ohms to 11,100 megohms. List price $100.

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SECTION MEETINGS

ATLANTA

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.


CINCINNATI
"Deflection-Type High-Voltage Supplies for Television Receivers," by Madison Cawein, The Farnsworth Company; April 16, 1946.

CLEVELAND

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


"Wire versus Disk Recorders for Military Aircraft," by Harry Schecter, Air Material 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.


(Continued on page 40A)

Proceedings of the I.R.E. and Waves and Electrons June, 1946
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.
PRODUCT DURABILITY

Problem: To improve life and service of gibs and retainer plates on high speed sanders. Parts must be able to withstand considerable abuse.

Solution: The problem was solved by the use of plastics. From the big family of INSUROK Precision Plastics, Richardson Plasticians selected Laminated INSUROK, grade CG. For this material has a high natural graphitic content and is especially suited for parts subject to friction and hard usage.

Richardson, for many years, has been helping to solve the plastics problems of industry. Our experience is at your service. You will find it a diversified service, with skilled plasticians ready to help you mold or laminate whatever grade and type of INSUROK is best for your application.

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LOCKLAND, CINCINNATI 15, OHIO  FOUNDED 1858  Sales Headquarters: MELROSE PARK, ILL.
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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 radio-phone 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.

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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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JOHNSON designed and built Pressurized Capacitors are available in fixed, variable and fixed-variable combination models with RMS voltage ratings up to 30,000 volts unmodulated and maximum capacitance range of 125 to 10,000 mmf.

These JOHNSON capacitors are ideal for handling circulating currents of high power transmitters and are widely used in tank circuits and antenna networks, as coupling capacitors for shunt excited vertical radiators and in high frequency equipment.

Built to assure positive pressure sealing, JOHNSON Pressurized Capacitors in actual use, have given trouble-free service for many years. They are electrically and mechanically engineered to assure highest operating efficiency and to withstand normal pressure with a large factor of safety.

JOHNSON Pressurized Capacitors offer you maximum capacity with minimum size and cost.


Write Dept. S for Data Sheet 2P Describing JOHNSON Pressurized Capacitors.

E. F. JOHNSON CO. • WAASECA • MINNESOTA

(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.

TORONTO
"The Role of the Ionosphere in Radio Communication," by N. Rostoker, University of Toronto; February 25, 1946.
"Cathode Follower," by G. F. G. Weeden, University of Toronto; February 25, 1946.
"Vacuum-Tube Voltmeters," by G. R. Slemon, University of Toronto; February 25, 1946.

SUBSCRIPTIONS
SOUTH BEND

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., Ca-
town, 28 Md.
Brownell, G. T., Majestic Radio and Tele-
vision 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 Estagh Ave., Had-
donfield, 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
Bluffs, N. Y.

(Continued on page 44.)
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Proceedings of the I.R.E. and Waves and Electrons June, 1946 43a
There’s no DOUBT about it!

...That’s the big advantage of any antenna designed and built by Blaw-Knox.

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OF BLAW-KNOX COMPANY
2058 Farmers Bank Building • Pittsburgh, Pa.

BLAW-KNOX VERTICAL RADIATORS
FM and TELEVISION

(Continued from page 41A)

Ginzton, E. L., 3 Raymond Court, Garden City, L. I., N. Y.
Hammann, P. L., Bell Telephone Laboratories, Whippany, N. J.
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.
Petrov, G., Box 1300, 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 Duflerin 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 Itoe Ave., Akron 1, Ohio
Stout, G. P., 324 Broadway 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

Allop, R. C., 30 Trafalgar Ave., Roseville, Sydney, New South Wales, Australia
Arditi, M., 157 W. 57th St., New York 19, N. Y.
Brand, P. M., 27 Mill Cove, Lamton Mills, Toronto 9, Ont., Canada
Franz, G. R., 463 West St., New York 14, N. Y.
Gillson, M. H., 19 Oliphant Dr., Morris-town, N. J.
Hanson, G. N., Meadow Lane, North Shore Acres, Glen Cove, L. I., N. Y.
Kohnbaas, H. T., 67 Broad St., New York 4, N. Y.
Wayne, 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.
Brook, H. R., 2535 Montrose Ave., Montrose, Calif.
Broome, N., 1256 New York Ave., Brooklyn 3, N. Y.
Clews, T. W., 202 Frederick St., Kitchener, Ont., Canada

(Continued on page 46A)
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.

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.

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
DETECTS SMALL LEAKS

Condensers with even the slightest leakage will not get by this compact, modern tester. You get positive indication on the electron ray tube and the correct reading on the easy-to-read expanded scale.

CONDENSER TESTER
MODEL 650-A
Range—.00001 to 1,000 mfd.

Automatic Push Button Controlled—Amazing in speed and simplicity of use. Capacity readings almost instantaneous! Leakage test by just pressing a button.

The Model 650 is a modern accurate and complete instrument for detecting faulty condensers—Electrolytic, Paper or Mica. New method for Leakage Test reveals otherwise unnoticed condenser defects.

Scale is Glass Enclosed and is equipped with the new Jackson Scale Expander indicating pointer — doubles effective scale length.

Measures All Values—Direct reading in Microfarads.

Ranges
.00001 to .001 mfd. .1 to 100 mfd. .001 to .1 mfd. 50 to 1000 mfd.

Measures Power Factor on direct reading dial. Power Factor range calibrated from 0 to 60%.

Complete Selection of Test Voltage. 20 volts to 500 volts.

Electron Ray Tube indicates exact balance or shows if leakage is present.

Instantaneous Leakage Indication—Counting of flashes eliminated. No other guess-work with this modern tester. Has special built-in amplifier stage which actually responds to slightest leakage, if present. Thus all leakage defects may be located.

JACKSON
Fine Electrical Testing Instruments

JACKSON ELECTRICAL INSTRUMENT COMPANY, DAYTON, OHIO
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.

**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.

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"
Single shaft passes through and locks with rotor of each unit.

Each unit can be wound to precise circuit requirements, as to resistance, taper, tap, hop-off.

Interlocking resistance ratios provide any desired voltage or current at given degree of rotation.

Note dual unit with screw-driver adjustment. Such assemblies are serving in the most intricate electronic assemblies.

For three or more controls in tandem, Clarostat Type 42 is the logical choice. The bakelite cases of these rheostats or potentiometers nest and lock together for a virtually solid casing. Metal end plates and tie rods insure a rigid assembly—even up to 20 units in tandem. This unit is the solution to your multiple-circuit control. Back-lash is completely eliminated. And it is typical of that Clarostat "know-how" which provides the answers to all your resistor, control or resistance-device problems.

Submit your problem!
skilled springmakers... AND practical, experienced engineers, SPECIALISTS in spring design and manufacture

At Accurate

It takes people to make springs. Ours are specialized, highly trained, long-experienced people—well qualified to give you the finest in spring craftsmanship.

Our engineers too, are an important reason why you'll like Accurate Spring Service. They're old hands at spring-making... they've developed manufacturing systems and procedures that enable us to handle your jobs with the greatest speed and efficiency. These Accurate engineers are at your service on spring design problems. You will benefit from their practical assistance in designing exactly the right spring for your application.

Why not try Accurate on your next job.

ACCURATE SPRING MFG. CO.
3835 W. Lake Street
Chicago 24, Illinois

Send for your copy of the new Accurate Spring Handbook. It's full of data and formulae which you will find useful. No obligation of course.

SPRINGS • WIREFORMS • STAMPINGS

Proceedings of the I.R.E. and Waves and Electrons June, 1946
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 and 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. Desires 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

ENGINEER
M.I.T. trained radar officer, BS physical chemistry Rutgers 1941, photochemical research, electronic teaching, vacuum 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 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.
4. Beat frequency oscillator, pitch adjustable from front panel.
5. AM/CW switch. Also turns on automatic volume control in AM position.
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.

**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.
- 6 TUBES: 1-12SA7 converter; 1-12SK7 IF amplifier; 1-12SQ7 second detector, AVC, first audio amplifier; 1-12SQ7 beat frequency oscillator, automatic noise limiter; 1-351.6GT 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 or 250 volts AC or DC. Power consumption on 117 volts is 29 watts.
Astatic Crystal Cartridges

The Astatic Corporation is the world's largest producer of Crystal Phonograph Pickup Cartridges. Astatic Crystal Cartridges are manufactured to meet today's exacting standards of performance and are individually tested and approved for output voltage and frequency response before being released for shipment. Astatic Cartridges are extensively used in an ever-growing field of new product applications, as well as for replacement purposes or the improvement of existing equipment.

Positions Wanted

(Continued from page 50A)

Positions Wanted

(Continued on page 54A)

Astatic Crystal Devices
manufactured under Brush Development Co. patents

IN CANADA

THE

Astatic Corporation

CONNEAHT, OHIO

PROCEEDINGS

PROCEEDINGS

52A

June, 1946
SELENIUM RECTIFIERS
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:

- Permanent characteristics.
- Adaptability to all types of circuits and loads.
- Unlimited life—no moving parts.
- Immunity to atmospheric changes.
- High efficiency per unit weight.
- Hermetically sealed assemblies available.
- From 1 volt to 50,000 volts RMS.
- From 10 micro-amperes to 10,000 amperes.
- Economical—No maintenance cost.

SELENIUM CORPORATION OF AMERICA
Affiliate of VICKERS, Incorporated
1719 WEST PICO BOULEVARD • LOS ANGELES 15, CALIFORNIA
Export Division: Frazer & Hansen, 301 Clay Street, San Francisco 11, Calif.
In Canada: Canadian Line Materials, Ltd., Toronto 13, Canada
Acme Electric transformers are designed to basic standards to which variations can be adapted to exactly meet the requirements of the application. For example, Mounting Type 100 is for horizontal mounting while type 101 is for vertical mounting, yet both are basically identical. And in either case, one or both mounting legs may be turned down for side mounting to save space. The number of leads or terminals may also be varied to comply to the electrical specifications desired. All things considered, Acme transformers made from standard parts to special specifications are available in hundreds of ratings and to exactly the physical dimensions, design and electrical characteristics you require. Acme Transformer Engineers will be glad to assist you by designing transformers to improve the performance of your product. Bulletin 168 gives more details.

THE ACME ELECTRIC & MFG. CO.
31 Water St.
CUBA, N. Y.

Positions Wanted

(Continued from page 32A)

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.

(Continued from page 48A)

Admission to Associate
Abernethy, R. L., 120 Frederick Ave., Babylon, L. I., N. Y.
Akers, R. F., 344 Churchill Rd., West Palm Beach, Fla.
Arteaga, W., 29 W. 82 St., New York 24, N. Y.
Barrett, F. C., Sunnyvale, Cheadle, Cheshire, England
Barrett, R. D., 1617 S. Flower St., Los Angeles 15, Calif.
Bell, E. P., Bell Machine Co., Oshkosh, Wis.
Bonvouloir, F. D., 60 Frederick St., Maple Hill, Newton, Conn.
Borden, T. G., 2200 Cheverly Ave., Cheverly, Hyattsville, Md.
Bullen, H. R., Simonds Saw and Steel Co., Lockport, N. Y.
Calhoun, D. C., Jr., 2835 N. E. 55 Ave., Portland 13, Ore.

MEMBERSHIP
(Continued from page 48A)

(Continued on page 54A)
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.
is a major element in Chicago Transformer's service to the Electronic Industry. If special transformer applications are involved in your new product plans, C. T.'s engineering staff offers the all-around experience and know-how that will best fit these items of your component requirements.
"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 99.99+% 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.

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.

The Zirmet ribbon is welded to the cathode shield support. In normal tube operation the Zirmet reaches a temperature of about 650°C.

Chemicals • Ores • Metals • Alloys

PHILADELPHIA • ASBESTOS • EXTON, PENNSYLVANIA
Every magnet individually tested in loud speaker structure before shipping...

Every magnet meets R. M. A. proposed standards...

Every magnet meets Arnold's minimum passing standards of 4,500,000 BHmax.

Here's what the individual touch means. Thousands of the nine different sizes of speaker magnets shown at right are now being turned out daily. Each one is individually tested in a loud speaker structure before shipping. Each magnet is made to meet R. M. A. proposed standard for the industry. Each magnet must meet Arnold's own minimum passing standard of 4,500,000 BHmax for Alnico V material. Thus by careful attention to the important "individual touch" in volume production can Arnold promise you top quality in each individual magnet you select.
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 1/2" 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.
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.

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 1/2 and 3/4 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.
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.
It's generally agreed that he can't. If he could, however, he would no longer be a leopard. For one of the first principles is that nothing can undergo a fundamental change and still retain its lineage.

We, at Stancor, apply this principle to our product...quality transformers. For we realize that any change in Stancor transformers, enabling us to capitalize on the peak demands, would mean a sacrifice in quality.

We're convinced, too, that this is your choice: that you, as a transformer user, in sustaining your valued position in the industry, endorse the Stancor policy of quality. In a sense, then, you dictate Stancor policy.

Like you, we are expending every effort to surmount today's knotty production and delivery problems, that we may soon be able to supply the same quality transformers...in ever increasing quantities.

Until that time Stancor's engineering facilities and industrial resourcefulness are available for the solution of your most urgent transformer problems.

S. H. Cohen
President

STANDARD TRANSFORMER CORPORATION
1500 NORTH HALSTED STREET • CHICAGO 22, ILLINOIS

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
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 (E_b): 8,000 v.
- Second grid voltage (E_c2): 250 v.
- Negative grid voltage (E_c1) for beam cutoff: 45 v. (+25, -20 v.)
- Grid drive (at 1 Ib-200 µa.): 38 v. max.
YOU CAN NOW GET THESE DAILY ESSENTIALS

INSTRUMENT & TESTER SWITCHES
12-14 and 20 position. Shorting; non-shorting 1-6 decks.

OPERATING TEMPERATURE TESTERS
Automatically compensated, typical range for ovens, 0-650°F.

400 CYCLE PORTABLES
Accuracy to ±0.3%; pocket size metal case; other ranges.

VACUUM-TUBE FREQUENCY METERS
Accuracy, ±0.25%; six specific bands, to 3600 cps. No drift.

MOST COMPACT FREQUENCY METERS
Matches standard 2½” panel instruments, 60, 120 cps.

ELAPSED TIME—FREQUENCY METERS
3¼” mounting; encourages periodic servicing and tube-life checking.

MULTIPLE RANGE PORTABLES
Standard—4 frequency groups at 3 voltages. Many special order variations.

POTENTIOMETER-PYROMETERS
Measures and follows temperatures continuously after initial balancing.

... 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
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.

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.
HIGH FREQUENCY PROBE

with INPUT CAPACITY of ½ to 1 MMF

Extends Measurement Range 10 Times
—50 to 500 Megacycles

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Westinghouse Resumes Fellowships

(Continued from page 64A)

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. Shouppe (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 inventors 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 transmitting 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)
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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 evaluated by the use of interpolated values of constants, and even with the complicated arrangements of conductors, a straightforward procedure can be outlined.

CHAPTER HEADINGS

General Principles; Geometric Mean Distances; Construction of and Method of Using the Collection of Working Formulas. CIRCUITS WHOSE ELEMENTS ARE STRAIGHT FILAMENTS. Parallel Elements of Equal Length; Mutual Inductance of Unequal Parallel Filaments; Mutual Inductance of Filaments Inclined at an Angle to Each Other: Circuits Composed of Combinations of Straight Wires; Mutual Inductance of Equal, Parallel, Cylindrical Winding Forms; Mutual Inductance of Rectangular Winding Forms. CIRCUITS COMPOSED OF CIRCULAR ELEMENTS. Mutual Inductance of coaxial Circular Filaments. Mutual Inductance of coaxial Circular Coils; Self-Inductance of Circular Coils of Rectangular Cross Section; Mutual Inductance of a Solenoid and a Cylindrical Circular Element; Mutual Inductance of Cylindrical Single-Layer Coils; Single-Layer Coils on Cylindrical Winding Forms; Special Types of Single-Layer Coils: Mutual Inductance of Cylindrical Elements With Parallel Axes; Mutual Inductance of Circular Filaments Whose Axes are Inclined to One Another; Mutual Inductance of Solenoids With Inclined Axes, and Solenoids and Circular Coils With Inclined Axes; Circuit Elements of Larger Cross Sections With Parallel Axes; Auxiliary Tables for Calculations With Formulas Involving Zonal Harmonic Functions: Formulas for the Calculation of the Magnetic Force Between Coils; High Freency Formulas. Durable cloth binding 6 x 9 295 pages $5.75

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<table>
<thead>
<tr>
<th>Q</th>
<th>DC RESISTANCE</th>
<th>INDUCTANCE VARIATION</th>
<th>TYPE &amp; SIZE OF WIRE</th>
<th>NO. OF TURNS</th>
<th>TYPE OF WINDING</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 meg. unit 50</td>
<td>18.14 ohm @23°C</td>
<td>420 microhenries ± 5%</td>
<td>325 to 750 microhenries</td>
<td>£90 S C</td>
<td>198 Multiple</td>
</tr>
<tr>
<td>10 meg. unit 10</td>
<td>1.90 ohm @19.5°C</td>
<td>84 microhenries ± 5%</td>
<td>4.75 to 14.25 microhenries</td>
<td>£38 S C</td>
<td>24.5 Multiple</td>
</tr>
<tr>
<td>30 meg. unit 10</td>
<td>1.26 ohm @20°C</td>
<td>0.7 microhenries ± 5%</td>
<td>0.35 to 1.0 microhenries</td>
<td>£28 £</td>
<td>7 Single layer</td>
</tr>
<tr>
<td>60 meg. unit 50</td>
<td>1.02 ohm @20°C</td>
<td>0.061 microhenries</td>
<td>0.065 to 0.095 microhenries</td>
<td>£28 £</td>
<td>2 Single layer</td>
</tr>
</tbody>
</table>

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Digest of Expiring Patents

Public Domain, a new weekly publication of the Scientific Development Corporation, 614 West 49 Street, New York 19, N. Y., appeared in May, 1946. Each issue will contain over 1000 patents due to expire four weeks after the date of the issue, plus a simplified index, and each patent shown will include a reproduction of a draftsman's drawing together with a digest of typical claims and salient features. Charter subscriptions are offered for one year at $45.00, for six months at $25.00, and for 10 weeks at $10.00.

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It makes for simplicity in purchasing,
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New Fields For Tubes
(Continued from page 68A)

Special-type tubes, including the photo-tube 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.

It is obvious the greatest peacetime problem is that of providing immediate utilization of war-expanded manufacturing facilities for power, cathode-ray, and special-type tubes. Although a number of years probably will elapse before production of such tubes will again reach wartime peaks, it is confidently expected that peacetime demand for these tubes will ultimately exceed peak wartime production. Television, for example, offers early promise of reaching that goal on cathode-ray tubes.

The prospects for immediate production, sales, and employment in the electron-tube industry compare very favorably with those of any other industry. There is literally no individual, no industry, no service, that is not a potential customer for electronic products or equipment and, therefore, for electron tubes. The potential tube business is limited primarily by man’s ingenuity in creating the buying power necessary for its realization, rather than by technical considerations or want of ideas.

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    (D) Sheets.
15. CHASSIS.
16. CHOOSE COILS:
    (A) A. Audio Frequency.
    (B) B. Power.
    (C) C. Radio Frequency.
    (D) D. Sheet.
17. CONNECTORS:
    (A) Binding Posts.
    (B) B. Precision.
    (C) C. Paper.
    (D) D. Oil Filled.
18. COILS:
    Condensers, see Capacitors.
19. CONVERTERS:
    (A) Frequency.
    (B) Rotary: see Motor Generators.
    (C) Vibration.
20. CONSULTING ENGINEERS:
    (A) A. Acoustic.
    (B) B. Electrical.
    (C) C. Mechanical.
    (D) D. Radio.
21. CONVERTERS:
    (A) A. Frequency.
    (B) Rotary: see Motor Generators.
    (C) Vibration.
22. CORE MATERIALS:
    (A) A. Complete Cores.
    (B) Laminations.
    (C) Powdered Iron.
23. CRYSTALS:
    (A) Oscillating Quartz.
    (B) Piezo-Electric.
    (C) Rectifier.
24. CUSTOM BUILDERS OF EQUIPMENT.
    Dials & Tuning Controls, see Hardware.
    Dics, Recording, see Recording Equipment.
25. DISTRIBUTORS & JOBBERS OF RADIO EQUIPMENT PARTS.
26. DRAFTING EQUIPMENT & SUPPLIES.
    Dynamotors, see Motor Generators.
27. ELECTRONIC CONTROL EQUIPMENT:
    (A) A. Air Conditioning Controls.
    (B) B. Burglar Alarm & Fire 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) A. Band Pass.
    (B) B. Noise Elimination.
    (C) C. Sound Effect.
31. FREQUENCY MEASURING EQUIPMENT:
    (A) A. Audio Frequency.
    (B) B. Primary Standards.
    (C) C. Radio Frequency.
    (D) 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) A. Binding Posts.
    (B) B. Bushings.
    (C) D. Flexible Shafts.
    (E) E. Lugs.
36. INDUCTION HEATING EQUIPMENT.
37. INDUCTORS.
38. INSULATION: (Also see Ceramics.)
    (A) A. Cloth.
    (B) B. Glass Seals.
    (C) C. Mica.
    (D) D. Varnished Cambric.
    (E) E. Paper.
39. JACKS.
40. KEYS:
    (A) A. Switching.
    (B) B. Telegraph.
    Knobs, see Moulded Products.
41. LACQUERS:
    (A) A. Finishing.
    (B) B. Fungus Proofing.
    (C) C. Protecting.
    (D) D. Waterproofing.
42. LOUDSPEAKERS & HEADPHONES.
    Lugs, see Hardware.
43. MACHINERY, FIXTURES, & TOOLS FOR RADIO & ELECTRONIC MANUFACTURING.
44. MAGNETS:
    (A) A. Electro.
    (B) B. Permanent.
    Measuring Equipment, see Test Equipment.
45. METALS:
    (A) A. Copper.
    (B) B. Ferrous.
    (C) C. Non-Ferrous.
    (D) D. Precious & Rare.
46. METERS:
    (A) A. Ammeters.
    (B) B. Frequency Indicating.
    (C) C. Power Level.
    (D) D. Vacuum Tube Voltmeters.
47. MICROPHONES.
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June, 1946

77A

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ADVERTISER'S INDEX

Section Meetings .................................................. 38A
Membership .......................................................... 42A
Positions Open ..................................................... 50A
Positions Wanted ................................................... 50A
Accurate Spring Mfg. Co. ........................................... 49A
Acme Electric & Mfg. Co. ........................................... 54A
Aerovox Corporation ............................................... 12A
Aircraft Radio Corp. ............................................... 61A
Allen-Bradley Company ........................................... 30A
Alliance Mfg. Co. .................................................. 25A
American Brass Company (Metal Hose Branch) .................. 69A
American Lava Corp. ............................................... 17A
American Phenolic Corp. ......................................... 6A
American Transformer Co. ........................................ 18A
Andrew Co. .......................................................... 60A
Arnold Engineering Co. .......................................... 58A
Astatic Corp. ....................................................... 52A
Automatic Mfg. Corp. .............................................. 43A
A. W. Barber Laboratories ........................................ 66A
Bell Telephone Laboratories ..................................... 32A & 3A
Blaw Knox Co. ..................................................... 44A
Billey Electric Company .......................................... 55A
W. J. Brown ......................................................... 73A
Browning Laboratories, Inc. .................................... 59A
Cambridge Thermionic Corp. .................................... 70A
Capital Radio Engineering Institute ............................. 75A
Allen D. Cardwell Mfg. Corp. ................................... 74A
Centralab ............................................................ 10A
Chicago Transformer ................................................ 56A
Clarostat Mfg. Co., Inc. ......................................... 48A
Sigmund Cohn & Co. .............................................. 64A
Collins Radio Co. .................................................. 23A
Communication Measurements Lab. ........................... 78A
Edward J. Content ................................................. 73A
Cornell Dubilier Electric Corp. ................................. Cover III
R. A. Dinz .......................................................... 73A
Drake Mfg. Co. ..................................................... 75A
Allen B. DuMont Labs., Inc. .................................... 16A, 63A
E. I. du Pont de Nemours & Co., Inc. ......................... 70A
Hugh H. Eby, Inc. .................................................. 31A
Stanley D. Eilenberger ........................................... 73A
Eitel-McCullough, Inc. ........................................... 80A
Electrical Reactance Corp. ...................................... 73A
Electronics Research Publishing Co. ........................... 66A
Fairchild Camera & Inst. Corp. ................................ 65A
Federal Tel. & Radio Corp. ....................................... 8A & 9A, 36A & 37A
F. T. Fisher's Sons ............................................... 73A
Foote Mineral Co. ................................................. 57A
General Aniline & Film Corp. ................................... 34A & 35A
General Electric Co. .............................................. 4A
General Radio Co. ................................................ Cover IV
Guardian Electric .................................................. 45A
Hallicrafters Company ............................................ 51A
Hammarlund Mfg. Company, Inc. .............................. 71A
Hewlett-Packard Company ...................................... 22A
Hytron Radio & Electronics Corp. ............................. 11A
International Nickel Co., Inc. .................................. 28A
International Resistance Co. .................................... 67A
International Tel. & Tel. Corp. .................................. 38A & 9A, 36A & 37A
Jackson Electrical Inst. Co. .................................... 46A
J. B. T. Instruments .............................................. 64A
E. F. Johnson Co. .................................................. 42A
Langvin Co. ........................................................ 72A
Machlett Laboratories, Inc. .................................... 29A
Manufacturers Screw Products .................................. 72A
Frank Massa ....................................................... 73A
Measurements Corporation ..................................... 68A
Mycalex Corp. of America ....................................... 1A
M. F. M. Osborne Associates .................................... 73A
National Carbon Co., Inc. ....................................... 15A
National Company, Inc. ......................................... 27A
National Vulcanized Fibre Co. .................................. 78A
Albert Prisman ..................................................... 73A
Press Wireless Mfg. Corp. ....................................... 5A
Presto Recording Corp. ........................................... 13A
Radio Corp. of America .......................................... 32A, 41A, 79A
Rawson Elect. Inst. Co. ........................................... 75A
Raytheon Mfg. Co. ............................................... 20A
Remler Co. Ltd. .................................................... 66A
Revere Copper & Brass, Inc. .................................... 19A
Richardson Company ............................................. 40A
John F. Rider Publishers ........................................ 68A
Rowe Industries ................................................... 73A
Selenium Corporation of America ............................... 53A
Shallcross Mfg. Company ......................................... 38A
Sherron Electronics Co. ......................................... 47A
Solar Mfg. Corp. .................................................. 33A
Sprague Electric Company ....................................... 14A
Stackpole Carbon Co. ............................................ 26A
Standard Transformer Corp. ..................................... 62A
Stuckiak Ceramic & Mfg. Co. .................................. 21A
Sun Radio & Electronics Co., Inc. ............................. 74A
Tech Labs. ........................................................... 74A
Triplett Electrical Instrument Co. ............................. 72A
Truscon Steel Co. .................................................. 39A
Tung-Sol Lamp Works, Inc. ..................................... 24A
United Transformer Company .................................... Cover II
D. Van Nostrand Company, Inc. ............................... 70A
Western Electric Company ....................................... 2A & 3A
Harold A. Wheeler ................................................ 73A
Wilcox Electronic Company, Inc. ............................. 7A
Paul D. Zottu ....................................................... 73A

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