Proceedings of the I·R·E

A Journal of Communications and Electronic Engineering

December, 1950

Volume 38 Number 12

For further details see pages 1458 and 1459.

PROCEEDINGS OF THE I.R.E.

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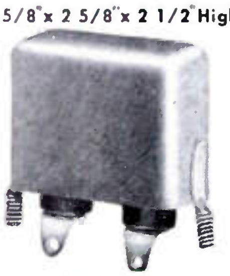
The Institute of Radio Engineers

PERMALLOY DUST TOROIDS FOR MAXIMUM STABILITY...

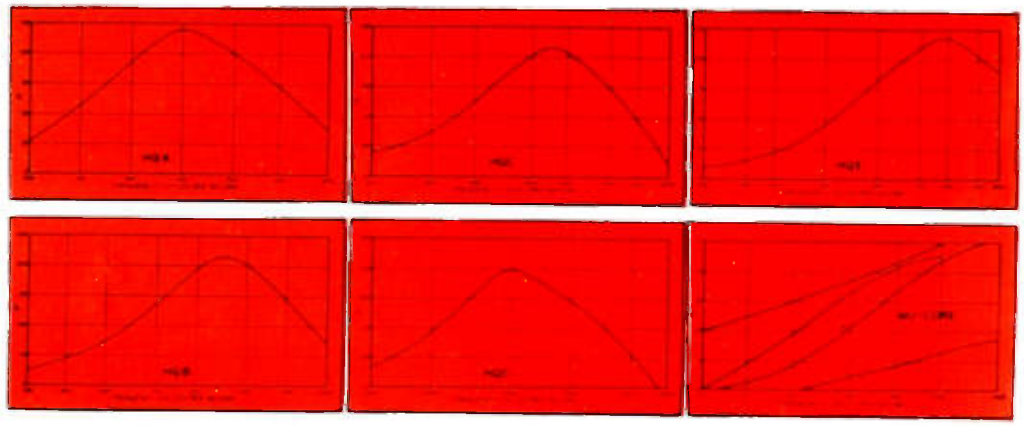
The UTC type HQ permalloy dust toroids are ideal for all audio, carrier and supersonic applications. HQA coils have Q over 100 at 5,000 cycles... HQB coils, Q over 200 at 4,000 cycles... HQC coils, Q over 200 at 30 KC... HQD coils, Q over 200 at 60 KC... HQE (miniature) coils, Q over 120 at 10 KC. The toroid dust core provides very low hum pickup... excellent stability with voltage change... negligible inductance change with temperature, etc. Precision adjusted to 1% tolerance. Hermetically sealed.

HQA, HQC, HQD CASE
1 13/16" Dia. x 1 3/16" High

HQB CASE
1 5/8" x 2 5/8" x 2 1/2" High

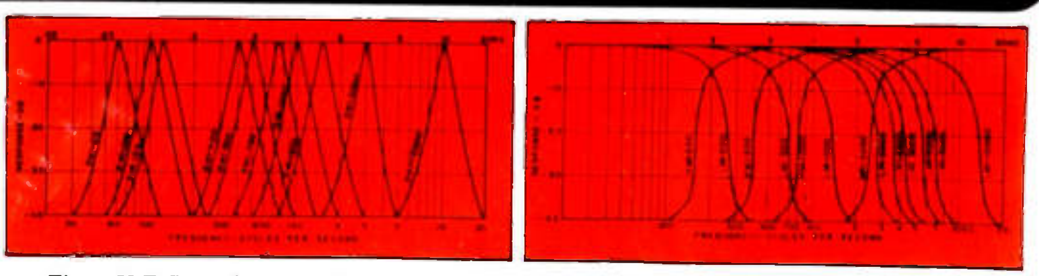


HQE CASE
1/2" x 1 5/16" x 1 3/16" High



Type No.	Inductance Value	Net Price	Type No.	Inductance Value	Net Price	Type No.	Inductance Value	Net Price
HQA-1	5 mhy.	$7.00	HQA-16	7.5 hy.	$15.00	HQC-1	1 mhy.	$13.00
HQA-2	12.5 mhy.	7.00	HQA-17	10. hy.	16.00	HQC-2	2.5 mhy.	13.00
HQA-3	20 mhy.	7.50	HQA-18	15. hy.	17.00	HQC-3	5 mhy.	13.00
HQA-4	30 mhy.	7.50	HQB-1	10 mhy.	16.00	HQC-4	10 mhy.	13.00
HQA-5	50 mhy.	8.00	HQB-2	30 mhy.	16.00	HQC-5	20 mhy.	13.00
HQA-6	80 mhy.	8.00	HQB-3	70 mhy.	16.00	HQD-1	.4 mhy.	15.00
HQA-7	125 mhy.	9.00	HQB-4	120 mhy.	17.00	HQD-2	1 mhy.	15.00
HQA-8	200 mhy.	9.00	HQB-5	.5 hy.	17.00	HQD-3	2.5 mhy.	15.00
HQA-9	300 mhy.	10.00	HQB-6	1. hy.	18.00	HQD-4	5 mhy.	15.00
HQA-10	.5 hy.	10.00	HQB-7	2. hy.	19.00	HQD-5	15 mhy.	15.00
HQA-11	.75 hy.	10.00	HQB-8	3.5 hy.	20.00	HQE-1	5 mhy.	6.00
HQA-12	1.25 hy.	11.00	HQB-9	7.5 hy.	21.00	HQE-2	10 mhy.	6.00
HQA-13	2. hy.	11.00	HQB-10	12. hy.	22.00	HQE-3	50 mhy.	7.00
HQA-14	3. hy.	13.00	HQB-11	18. hy.	23.00	HQE-4	100 mhy.	7.50
HQA-15	5. hy.	14.00	HQB-12	25. hy.	24.00	HQE-5	200 mhy.	8.00

UTC INTERSTAGE AND LINE FILTERS



FILTER CASE M
1 3/16" x 1 11/16"
1 5/8" - 2 1/2" High

These U.T.C. stock units take care of most common filter applications. The interstage filters, BMI (band pass), HMI (high pass), and LMI (low pass), have a nominal impedance at 10,000 ohms. The line filters, BML (band pass), HML (high pass), and LML (low pass), are intended for use in 500/600 ohm circuits. All units are shielded for low pickup (150 mv/gauss) and are hermetically sealed.

STOCK FREQUENCIES
(Number after letters is frequency)
Net Price $25.00

BMI-60	BMI-1500	LMI-200	BML-400
BMI-100	BMI-3000	LMI-500	BML-1000
BMI-120	BMI-10000	LMI-1000	HML-200
BMI-400	HMI-200	LMI-2000	HML-500
BMI-500	HMI-500	LMI-3000	LML-1000
BMI-750	HMI-1000	LMI-5000	LML-2500
BMI-1000	HMI-3000	LMI-10000	LML-4000
			LML-12000

United Transformer Co.

150 VARICK STREET NEW YORK 13, N. Y.

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

"IRE meetings are great!"

The amazing speed of development in television, radio communications and electronics can, in a large measure, be traced to the free interchange of ideas between engineers. In the long run, this becomes an "exchange," and those who idealistically "give" also "receive" and all that participate thereby profit. This has been the objective of IRE Conferences and Meetings since 1912!

HIGH FREQUENCY MEASUREMENTS CONFERENCE

Dates:
January 10-12, 1951

Place:
Department of the Interior Auditorium, Washington, D.C.

Program:

Second Forum on High Frequency Measurement sponsored jointly by the American Institute of Electrical Engineers, the Institute of Radio Engineers and the National Bureau of Standards. This event also is a part of the celebration of the Semicentennial of the National Bureau of Standards.

The sessions cover the subjects of "Measurements of Frequency and Time"; "Impedance"; "Power and Attenuation"; and "Transmission and Reception."

A highlight of the conference will be three demonstration lectures on Thursday evening, January 11th which will constitute the Annual Joint Meetings of the local AIEE and IRE Sections. A Microwave Spectroscope and a Recording Microwave Refractometer will be demonstrated at this session, and Dr. Winston E. Kock of Bell Telephone Laboratories will be an outstanding speaker.

Registration fee is $2.00 if paid in advance, and $2.50 at the conference. Mail registrations to Mr. W. F. Snyder, National Bureau of Standards, Washington, D.C.

IRE NATIONAL CONVENTION & RADIO ENGINEERING SHOW

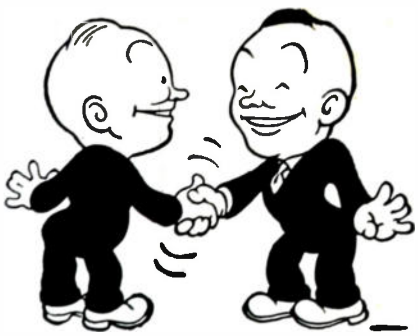
Dates:
March 19-22, 1951

Place:
Waldorf Astoria Hotel and Grand Central Palace

Program:

24 Technical Sessions on every field of "Waves and Electrons" from Audio to Nucleonic. Practical engineering sessions on television, quality control, and components, papers on advances in Instrumentation, the popular Tuesday Evening Symposium on Television, all combine to carry out the theme of the 1951 Convention, "Advance with Radio-Electronics."

Add to this the 250 exhibits of the Radio Engineering Show, and the fellowship of meeting your associate engineers in your professional field, and you have a meeting you cannot miss.



COMING MEETINGS CALENDAR

IRE-AIEE Conference on Electron Tubes for Computers, Washington, D. C., December 14-15

AAAS Annual Meeting, Cleveland, Ohio, December 26-30

AIEE-IRE-NBS High Frequency Measurements Conference, Hotel Statler, Washington, D. C., January 10-12

1951 IRE National Convention, Waldorf Astoria Hotel, New York, N. Y., March 19-22

IRE Southwestern Conference, Dallas, Texas, April 20-21, 1951

1951 Annual Meeting of the Engineering Institute of Canada, Mount Royal Hotel, Montreal, May 9-11

1951 IRE Technical Conference on Airborne Electronics, Biltmore Hotel, Dayton, Ohio, May 23-25

1951 IRE West Coast Convention, San Francisco, Calif., August 29-31

IRE Conferences and Conventions promote electronic progress!

Proceedings of the I.R.E. December, 1950, Vol. 38, No. 12. Published monthly by The Institute of Radio Engineers, Inc., at 1 East 79 Street, New York 21, N.Y. Price $2.25 per copy. Subscriptions: United States and Canada, $18.00 a year; foreign countries $19.00 a year. Entered as second class matter, October 26, 1927, at the post office at Menasha, Wisconsin, under the act of March 3, 1879. Acceptance for mailing at a special rate of postage is provided for in the act of February 28, 1925, embodied in Paragraph 4, Section 412, P. L. and R., authorized October 26, 1927.

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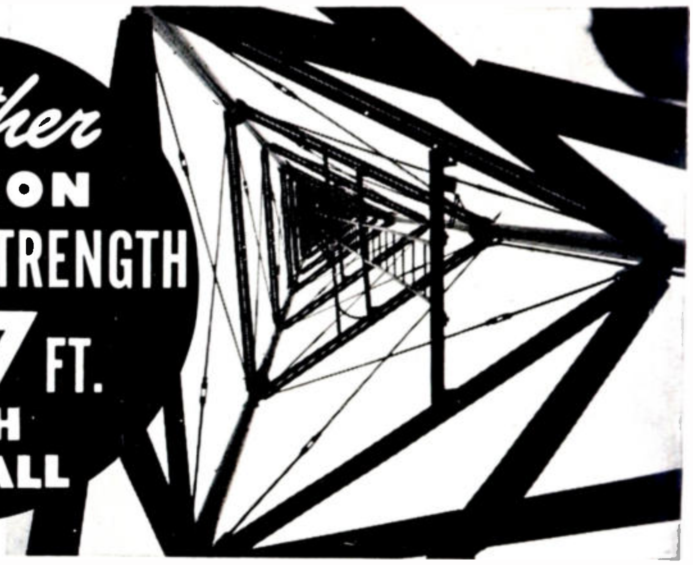


A RELIABLE SOURCE OF SUPPLY *for* DEPENDABLE RESISTORS *for* OVER 20 YEARS

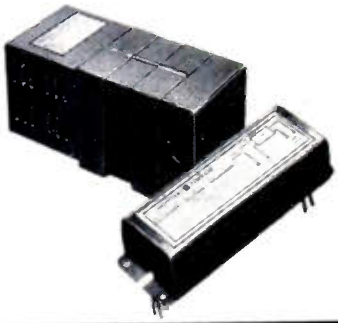
STACKPOLE

... FIXED RESISTORS
VARIABLE RESISTORS ... IRON CORES ...
CERAMAG® CORES ... LINE, SLIDE
AND ROTARY SWITCHES ...
CARBON VOLTAGE REGULATOR
DISCS ... MOLDED COIL FORMS
... GA "GIMMICK" CAPACITORS, ETC.

Electronic Components Division
STACKPOLE CARBON COMPANY • ST. MARYS, PA.

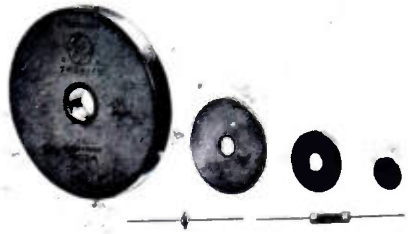
Digest

TIMELY HIGHLIGHTS ON G-E COMPONENTS



LINE-VOLTAGE STABILIZERS —get rid of ups and downs!

When you're after a steady 115 volts at the input of your equipment and the line is fluctuating anywhere between 95 and 130, use a G-E voltage stabilizer. These units use a special transformer circuit to provide a stabilized output voltage within ±1% of 115 volts for fixed, unity-power-factor loads. Fast response of G-E stabilizer restores normal output voltage in less than three cycles. 15-, 25- and 50-va stabilizers are small enough to mount on radio or electronic instrument chassis (2 inches high, 9 inches long). Standard ratings up to 5000 va are available in larger sizes. Write for Bulletin GEA-3634.



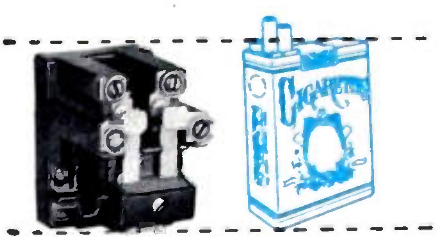
THYRITE— R varies inversely as E^4

With the unique electrical property of varying inversely in resistance as the fourth power (or even higher) of the applied voltage, Thyrite* resistance material has solved many problems for the design engineer.

Use it with a-c, d-c, or short duration pulses; for such applications as the limiting of voltage surges, stabilization of rectifier output voltages, controlling of voltage-selective circuits, and potentiometer division of voltages.

Thyrite comes in disk form in diameters from 0.25 to 6.00 inches, with or without mounting holes. Smaller sizes are furnished with wire leads. See Bulletin GEA-4138.

*Registered Trade Mark of General Electric Co.



TYPE HMA RELAYS—up to 30 amps, closing

The G-E Type HMA relay is only the size of cigarette package, but it closes at currents up to 30 amperes! HMA relays have self aligning, silver-to-silver contacts; are positive in action, instantaneous in operation. They're available in either back or front connected models. For coil voltages of 6, 12, 24, 32, 48, or 125 d-c; 115 or 230 a-c. Single- or double-break contacts. Bulletin GEA-5457.

General Electric Company, Section E667-8
Apparatus Department, Schenectady 5, N. Y.

Please send me the following bulletins:

Indicate
(V) for reference only
(X) for planning an immediate project

☐ GEA-3634 Voltage stabilizers
☐ GEA-4138 Thyrite
☐ GEA-5457 HMA relays

Name ____________________

Company ____________________

Address ____________________

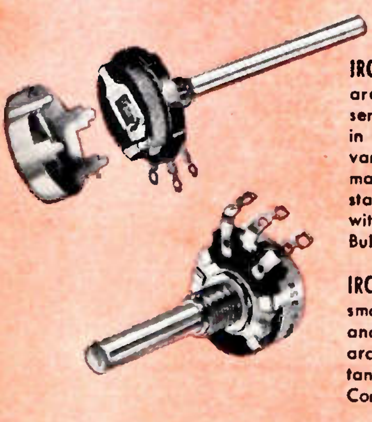
City ____________ State ____________

A complete line

for resistors too!

Unusual *combinations of characteristics* required in today's critical electronic circuits demand a complete range of resistor types. Specializing in resistors, IRC makes the widest line in the industry. This means ease of procurement—a single dependable source of supply for *all* your resistance needs. It also means unbiased recommendations—no substitution of units "just as good". IRC's complete line of products; complete research and testing facilities; complete network of licensees for emergency production—all add up to complete satisfaction for you.

CONTROLS



IRC Type W Wire Wound Controls are designed for long, dependable service and balanced performance in every characteristic. These 2-watt variable wire wound units provide maximum adaptability to most rheostat and potentiometer applications within their power rating. Catalog Bulletin A-2.

IRC New Type Q Controls feature small $^{15}/_{16}$" size, rugged construction and superior performance. Increased arc of rotation permits same resistance ratios successful in larger IRC Controls. Catalog Bulletin A-4.

PRECISION RESISTORS

IRC Precision Wire Wounds offer a fine balance of accuracy and dependability for close-tolerance applications. Extensively used by leading instrument makers, they excel in every significant characteristic. Catalog Bulletin D-1.

IRC Deposited Carbon PRECISTORS combine accuracy and economy for close-tolerance applications, where carbon compositions are unsuitable and wire-wound precisions too expensive. Catalog Bulletin B-4.

IRC Matched Pairs provide a dependable low-cost solution to close-tolerance requirements. Both Type BT and BW Resistors are available in matched pairs. Catalog Bulletin B-3.

IRC Sealed Precision Voltmeter Multipliers are suitable and dependable for use under the most severe humidity conditions. Each consists of several IRC Precisions mounted and interconnected, encased in a glazed ceramic tube. Catalog Bulletin D-2.

is essential

HIGH FREQUENCY and HIGH POWER RESISTORS

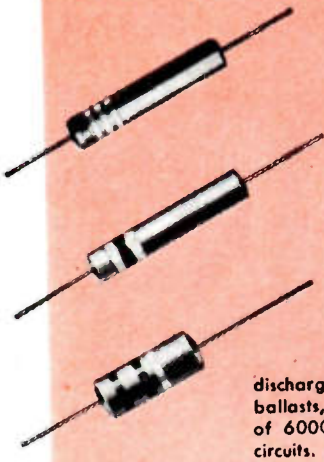
IRC Type MP High Frequency Resistors afford stability with low inherent inductance and capacity in circuits involving steep wave fronts, high frequency measuring circuits and radar pulse equipment. Available in sizes from ¼ to 90 watts. Catalog Bulletin F-1.

Type MV High Voltage Resistors utilize IRC's famous filament resistance coating in helical turns on a ceramic tube to provide a conducting path of long, effective length. Result: Exceptional stability even in very high resistance values. Catalog Bulletin G-1.

IRC Type MVX High Ohmic, High Voltage Resistors meet requirements for a small high range unit with axial leads. Engineered for high voltage applications, MVX has exceptional stability. Catalog Bulletin G-2.

IRC Type MPM High Frequency Resistors are miniature units suitable for high frequency receiver and similar applications. Stable resistors with low inherent inductance and capacity. Body only ⅜" long. Catalog Bulletin F-1.

INSULATED COMPOSITION and WIRE WOUND RESISTORS

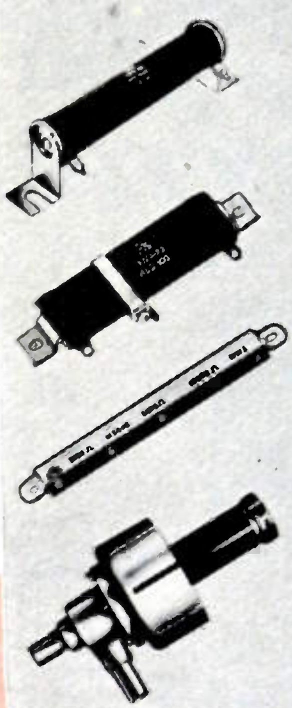


IRC Advanced Type BT Resistors meet and beat JAN-R-11 Specifications at ⅓, ½, 1 and 2 watts—combine extremely low operating temperature with excellent power dissipation. Catalog Bulletin B-1.

IRC Type BW Wire Wound Resistors are exceptionally stable, inexpensive units for low range requirements. Have excellent performance records in TV circuits, meters, analyzers, etc. Catalog Bulletin B-5.

IRC Type BTAV High Voltage Resistors, developed for use as discharge resistors in fluorescent "Quick Start" ballasts, withstand momentary peak surge of 6000 volts. Also suited to TV bleeder circuits. Catalog Bulletin B-1.

POWER RESISTORS



IRC Fixed and Adjustable Power Wire Wounds give balanced performance in every characteristic—are available in a full range of sizes, types and terminals for exacting, heavy-duty applications. Catalog Bulletin C-2.

IRC Type FRW Flat Wire Wound Resistors fulfill requirements of high wattage dissipation in limited space—may be mounted vertically or horizontally, singly or in stacks. Catalog Bulletin C-1.

IRC Type MW Wire Wound Resistors offer low initial cost, lower mounting cost, flexibility in providing taps, and saving in space. Completely insulated against moisture. Catalog Bulletin B-2.

IRC Type LP Water-Cooled Resistors for TV, FM and Dielectric Heating Applications. Cooled internally by high velocity stream of water; adjustable to local water pressure and power dissipation up to 5 K.W.A.C. Catalog Bulletin F-2.

Wherever the Circuit Says —ʌʌʌ—

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

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IRC

INTERNATIONAL RESISTANCE COMPANY
PHILADELPHIA 8, PENNSYLVANIA

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

INTERNATIONAL RESISTANCE CO.
405 N. BROAD ST., PHILADELPHIA 8, PA.

Please send me Technical Data Bulletins checked below:

☐ Bulletin A-2 (W)	☐ Bulletin B-4 (DC)	☐ Bulletin F-1 (MP)
☐ Bulletin A-4 (Q)	☐ Bulletin B-5 (BW)	☐ Bulletin F-1 (MPM)
☐ Bulletin B-1 (BT)	☐ Bulletin C-1 (FRW)	☐ Bulletin F-2 (LP)
☐ Bulletin B-1 (BTAV)	☐ Bulletin C-2 (PWW)	☐ Bulletin G-1 (MV)
☐ Bulletin B-2 (MW)	☐ Bulletin D-1 (WW)	☐ Bulletin G-2 (MVX)
☐ Bulletin B-3 (M/P)	☐ Bulletin D-2 (MF)	

NAME ....

TITLE ....

COMPANY ....

ADDRESS ....

CITY .... ZONE ...... STATE ....

J. F. ARNDT & CO., ADV. AGENCY

STANDARD RI-FI* METERS

14kc *to* 1000mc!

DEVELOPED BY **STODDART**
FOR THE ARMED FORCES.

AVAILABLE COMMERCIALLY.

VHF!

**15 MC
to
400 MC**

NMA - 5

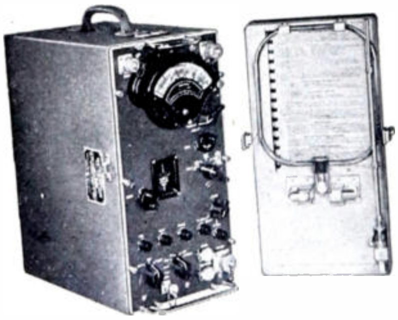
Commercial equivalent of TS-587/U. Sensitivity as two-terminal voltmeter, (95 ohms balanced) 2 microvolts 15-125 MC; 5 microvolts 88-400 MC. Field intensity measurements using calibrated dipole. Frequency range includes FM and TV Bands.

VLF!

**14 KC
to
250 KC**

NM - 10A

Commercial equivalent of AN/URM-6. A new achievement in sensitivity! Field intensity measurements, 1 microvolt-per-meter using rod; 10 microvolts-per-meter using shielded directive loop. As two-terminal voltmeter, 1 microvolt.



HF!

**150 KC
to
25 MC**

NM - 20A

Commercial equivalent of AN/PRM-1. Self-contained batteries. A.C. supply optional. Sensitivity as two-terminal voltmeter, 1 microvolt. Field intensity with ½ meter rod antenna, 2 microvolts-per-meter; rotatable loop supplied. Includes standard broadcast band, radio range, WWV, and communications frequencies.

UHF!

**375 MC
to
1000 MC**

NM - 50A

Commercial equivalent of AN/URM-17. Sensitivity as two-terminal voltmeter, (50-ohm coaxial input) 10 microvolts. Field intensity measurements using calibrated dipole. Frequency range includes Citizens Band and UHF color TV Band.

Since 1944 Stoddart RI-FI* instruments have established the standard for superior quality and unexcelled performance. These instruments fully comply with test equipment requirements of such radio interference specifications as JAN-I-225, ASA C63.2, 16E4(SHIPS), AN-I-24a, AN-I-42, AN-I-27a, AN-I-40 and others. Many of these specifications were written or revised to the standards of performance demonstrated in Stoddart equipment.

The rugged and reliable instruments illustrated above serve equally well in field or laboratory. Individually calibrated for consistent results using internal standard of reference. Meter scales marked in microvolts and DB above one microvolt. Function selector enables measurement of sinusoidal or complex waveforms, giving average, peak or quasi-peak values. Accessories provide means for measuring either conducted or radiated r.f. voltages. Graphic recorder available.

***Radio Interference and Field Intensity.**

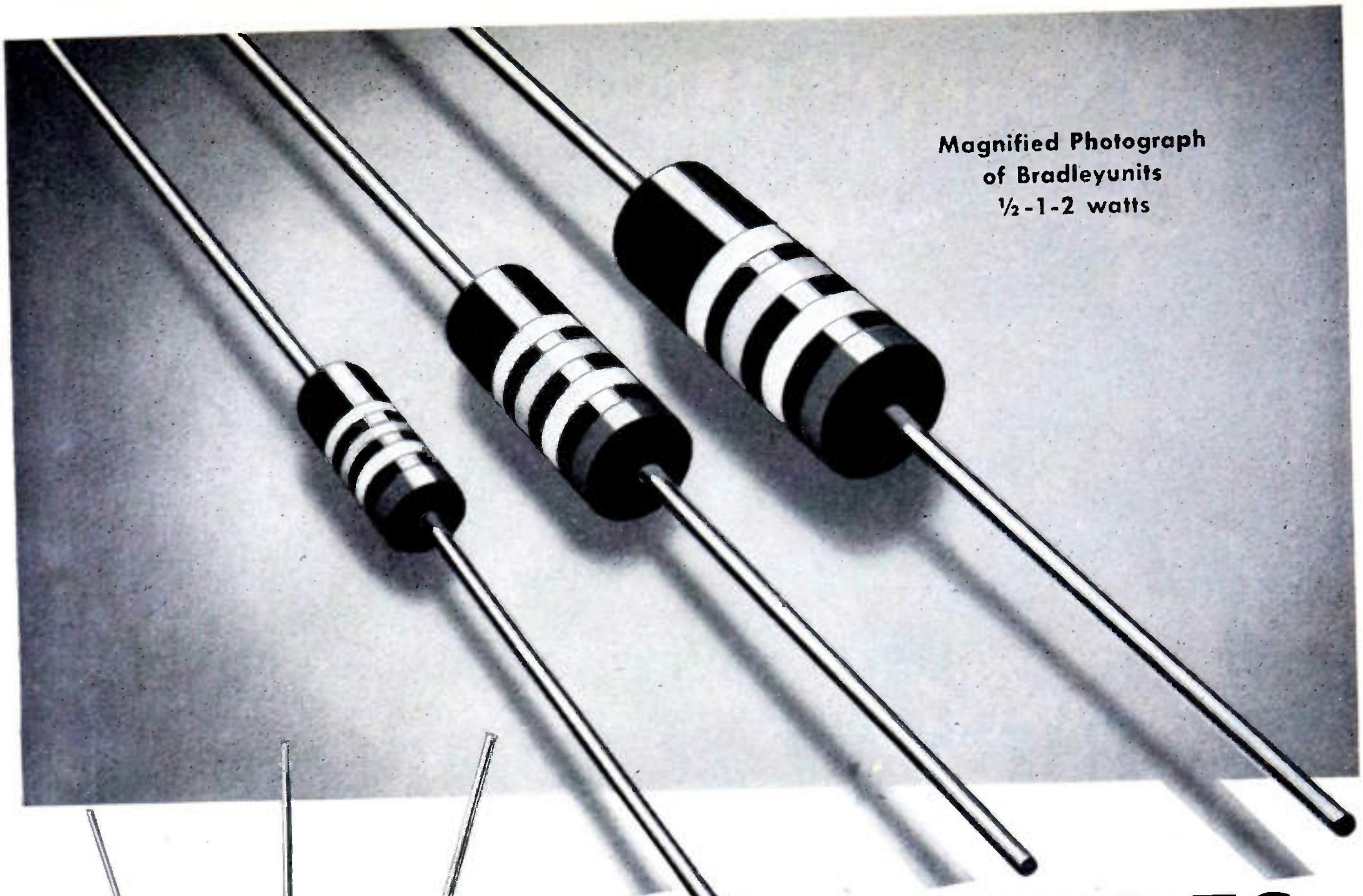
Precision Attenuation for UHF!

Less than 1.2 VSWR to 3000 MC.
Turret Attenuator:
0, 10, 20, 30, 40, 50 DB.
Accuracy ± .5 DB.
Patents applied for.

STODDART AIRCRAFT RADIO CO.

•

6644 SANTA MONICA BLVD., HOLLYWOOD 38, CALIF.
Hillside 9294



BRADLEYUNITS

"Tops" in Permanent Performance

. . . because rated at 70C

ACTUAL SIZE

Rating	L	D
½-W	3/8"	9/64"
1-W	9/16"	7/32"
2-W	11/16"	5/16"

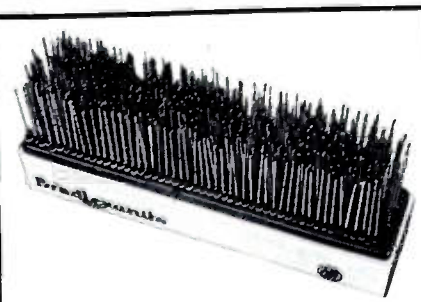
Bradleyunit resistors have permanent characteristics, because they are rated to operate continuously at 70C ambient temperature . . . not 40C. They can withstand extremes of temperature, pressure, and humidity without deterioration.

Bradleyunits are solid molded with high mechanical strength. They need no wax impregnation to pass salt water immersion tests. The leads are differentially tempered to prevent sharp bends.

Bradleyunits are made in standard R.M.A. values in ½ and 2 watt ratings from 10 ohms to 22 megohms; 1 watt from 2.7 ohms to 22 megohms.

Let us send you a complete A-B resistor chart.

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



The A-B honeycomb carton prevents tangling of leads and saves time.

A-B Quality

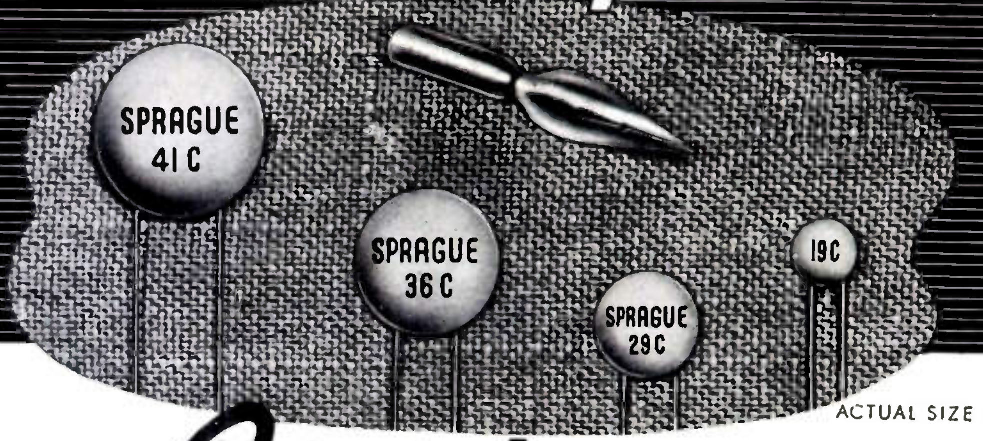
ALLEN-BRADLEY

FIXED & ADJUSTABLE RADIO RESISTORS

Sold exclusively to manufacturers QUALITY of radio and electronic equipment

TINY • DEPENDABLE • SPACE-SAVING

Cera-mite* Capacitors



ACTUAL SIZE

THE *First* COMPLETE DISC CERAMIC LINE

Sprague-Herlec Cera-mite Capacitors are a *"must"* for modern television circuits.

Now available in NP0 and N750 temperature-compensating bodies and in two different high-K bodies, Cera-mites meet most application needs in the 10 mmf to 15,000 mmf capacitance range.

These miniature capacitors offer set designers maximum space economy, ease of mounting, and improved very-high-frequency performance.

The flat disc with uni-directional lead construction has minimum self-inductance and a higher self-resonant frequency than a tubular design; hence improved v-f bypass efficiency.

Sprague-Herlec Engineering Bulletin 601B gives the complete list of standard ratings as well as performance specifications. Write for your copy today!

*Trademark

SPRAGUE ®

PIONEERS IN ELECTRIC AND ELECTRONIC DEVELOPMENT

SPRAGUE ELECTRIC COMPANY
North Adams, Massachusetts

THE HERLEC CORPORATION • Milwaukee 3, Wisconsin
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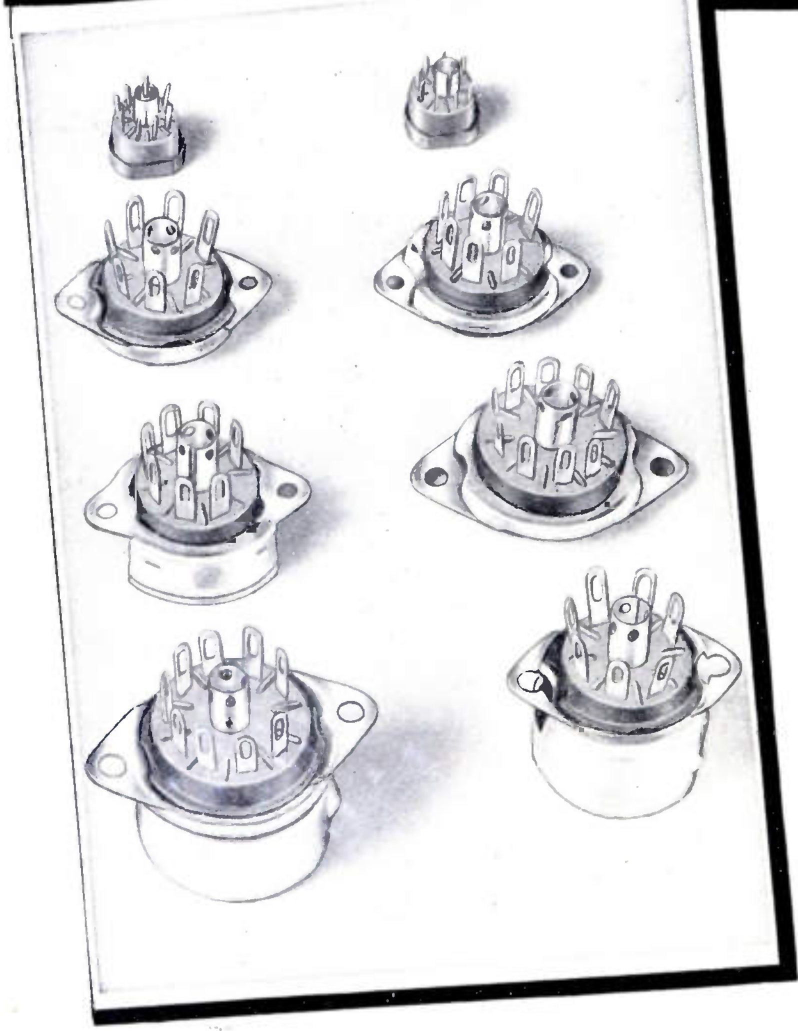
MYCALEX

MINIATURE TUBE SOCKETS

7-PIN and 9-PIN . . . and SUBMINIATURES

PREMIUM INSULATION PRICED COMPETITIVELY



Now MYCALEX offers both 7-pin and 9-pin miniature tube sockets . . . with superior low loss insulating properties, *at new low prices* that offer ceramic quality for the cost of phenolics.

MYCALEX miniature tube sockets are injection molded with precision that affords uniformity and extremely close tolerances. MYCALEX insulation has high dielectric strength, very low dielectric loss, high arc resistance and great dimensional stability.

Produced in two grades: MYCALEX 410 conforms to Grade L4 specifications, having a loss factor of only .015 at 1 MC. It is priced comparably with mica filled phenolics.

MYCALEX 410X is for applications where low cost of parts is vital. It has a loss factor only one-fourth that of "everyday" quality insulating materials, and a cost no greater.

Prices gladly quoted on your specific requirements. Samples and data sheets by return mail. Our engineers will cooperate in solving your problems of design and cost.

Mycalex Tube Socket Corporation

"Under Exclusive License of Mycalex Corporation of America"

30 Rockefeller Plaza, New York 20, N.Y.

SINCE 1919 MYCALEX THE INSULATOR TRADE MARK REG. U.S. PAT. OFF.

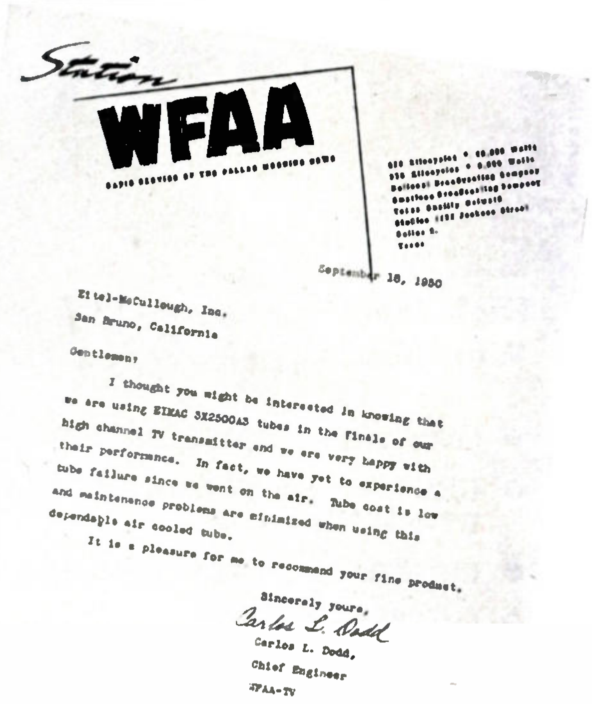
MYCALEX CORP. OF AMERICA

"Owners of 'MYCALEX' Patents"

Executive Offices: 30 Rockefeller Plaza, New York 20, N. Y. **Plant and General Offices: Clifton, N. J.**

CARLOS L. DODD
CHIEF ENGINEER WFAA-TV, DALLAS, TEXAS
TRANSMITTER—DUMONT 5 KW. CHANNEL 8.

From WFAA-TV,
More Proven Performance of the Eimac 3X2500A3



Station **WFAA**

September 18, 1950

Eitel-McCullough, Inc.
San Bruno, California

Gentlemen:

I thought you might be interested in knowing that we are using EIMAC 3X2500A3 tubes in the finals of our high channel TV transmitter and we are very happy with their performance. In fact, we have yet to experience a tube failure since we went on the air. Tube cost is low and maintenance problems are minimized when using this dependable air cooled tube.

It is a pleasure for me to recommend your fine product.

Sincerely yours,

Carlos L. Dodd

Carlos L. Dodd,
Chief Engineer
WFAA-TV

The Eimac 3X2500A3 is one of the outstanding vacuum tube developments made during recent years. Consistent performance, long life, and low cost account for its filling the key socket positions in many important recently designed equipments.

The 3X2500A3 is a compact, air-cooled triode. Its coaxial construction results in minimum lead inductance, excellent circuit isolation, and convenience of use with coaxial plate and filament tank circuits. For AM service it is FCC rated for 5000 watts per tube as a high-level modulated amplifier. It has comparatively low plate-resistance, high transconductance, and will provide effective performance over a wide range of plate voltages at frequencies extending well into the VHF.

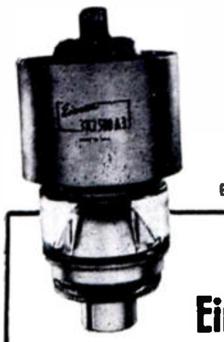
Reports from many engineers, like Mr. Dodd of WFAA-TV, confirm the outstanding transmitter performance, simplified maintenance, and low tube replacement cost made possible through the use of the Eimac 3X2500A3. Consider this unequalled triode for your applications . . . complete data are free for the asking.

Eimac 3X2500A3

GENERAL CHARACTERISTICS

ELECTRICAL		
Filament: Thoriated tungsten		
Voltage		7.5 volts
Current		48 amperes
Maximum starting current		100 amperes
Amplification Factor (Average)		20
Direct Interelectrode Capacitances (Average)		
Grid-Plate		20 uufd
Grid-Filament		48 uufd
Plate-Filament		1.2 uufd
Transconductance ($i_b = 830$ ma., $E_b = 3000$ v.)		20,000 umhos
MECHANICAL		
Cooling		Forced air
Maximum Overall Dimensions:		
Length		9.0 inches
Diameter		4.25 inches
Net Weight		5.8 pounds
RADIO FREQUENCY POWER AMPLIFIER		
Ground-Grid Circuit		
Class-C FM Telephony		
TYPICAL OPERATION (110 Mc., per tube)		
D-C Plate Voltage	3700	4000 volts
D-C Grid Voltage	—450	—550 volts
D-C Plate Current	1.8	1.85 amps.
D-C Grid Current	225	275 ma.
Driving Power (Approx.)	1600	1900 watts
Useful Power Output	6850	7500 watts

*COMPLETE DATA AVAILABLE FREE



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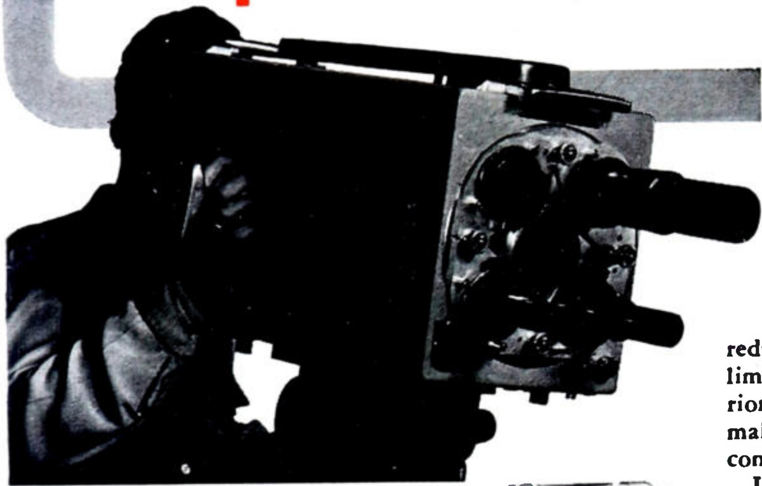
the 3X2500A3 is another
Eimac contribution to electronic progress.

269

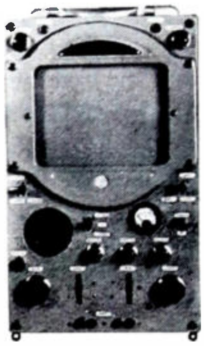
GPL Introduces First TV Camera Chain Designed from Start to Finish for Compactness and Ease of Operation



Built with the compact precision which distinguishes a quality watch from an alarm clock, GPL's new image orthicon camera chain is smaller, lighter, easier to use. It is the first camera chain that has been "human engineered" – designed from motion studies of cameramen and control personnel. It is the first with type and location of controls based on minimum movement and maximum ease and efficiency.

This simplification, together with size and weight reduction has been accomplished without any sacrifice or limitation whatever in performance or accessibility. Superior GPL circuit design provides a better picture than normally obtainable with image orthicon equipment. Complete control is provided for every studio or field requirement.

Logical components have been combined . . . fewer units make up a chain. A single chain consists of only 4 units; a triple chain, 12 including switching unit and master monitor. The camera, *with integral view finder*, is only 10¾" x 12½" x 22", weighs 75 lbs. instead of 100-105 lbs. The sync generator is a single portable unit including its own power supply. It may be easily removed from its case to go into a standard relay rack.



Compact GPL camera and control unit have been "human engineered" for easy, efficient use. Camera provides uniform focus adjustment for all lenses; iris is motor-controlled from rear of camera or from control unit, with lens opening shown on dials at both locations. Control unit has 8½" monitor tube.

SIMPLIFIED CONTROL

All controls are at the finger-tips of cameramen and camera control operators. Focus adjustment of all lenses is uniform; a given rotation of focus control produces the same shift in plane of focus for all lenses. The iris is motor-controlled, either from the rear of the camera or from the camera control unit. Dials on both camera and control unit indicate the lens opening. Negative feedback is used to stabilize video frequency response, eliminating an adjustment. Target and beam are controlled by thumbwheels next to convenient knobs for pedestal and gain.

IMPROVED SYNC GENERATOR

The sync generator, with its power supply, is a single unit, packaged for field use. Because binary counting circuits are used, and pulse width is controlled by delay lines, it provides circuit reliability better than present studio equipment. With this circuitry, all operator adjustments are eliminated.

READILY ADAPTABLE

GPL Camera Chains completely meet all studio and field requirements or may be readily adapted to supplement existing installations. *Before you make any camera chain investment, get all the facts on this new addition to GPL's outstanding line of TV studio equipment.*

Write, Wire or Phone for Details

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GENERATORS

10 to 7600 mc

10 to 500 mc -hp- 608A SIGNAL GENERATOR

Output range 0.1 μv. to 1.0 v. into 50 ohms. Accuracy ± 1 db. Direct reading frequency and output calibration, no charts or interpolation. CW, pulsed or amplitude modulated output (50 to 1,000,000 cps). Resetability better than 1 mc. Master oscillator power amplifier for widest modulation capabilities. Constant internal impedance 50 ohms. Maximum VSWR 1.2. $850 f.o.b. factory.

450 to 1,200 mc -hp- 610B SIGNAL GENERATOR

Output range 0.1 μv. to 0.1 v. into 50 ohms. Accuracy ± 1 db. Output and frequency directly set and read, no charts or interpolation. Modulation: internal or external pulsed, external amplitude, external square wave. Widely variable pulse length, repetition, and delay features. $925 f.o.b. factory.

800 to 2,100 mc -hp- 614A SIGNAL GENERATOR

Output range 0.1 μv. to 0.223 v. (1 mw). Accuracy ± 1 db. Single dial direct reading frequency and output, no charts or interpolation. CW, pulsed and FM output. Modulation: internal pulsed, FM, external pulsed. Widely variable pulsing, synchronizing, delay and triggering features. Extremely fast rise/decay time 0.1 μsec. Constant internal impedance 50 ohms, SWR 3 db. $1,950 f.o.b. factory.

1,800 to 4,000 mc -hp- 616A SIGNAL GENERATOR

Output range 0.1 μv. to 0.223 v. (1 mw). Accuracy ± 1 db. Single dial, direct reading frequency and output, no charts or interpolation. Output, modulation, and synchronization features identical with Model 614A. Like Model 614A, instrument automatically tracks frequency changes, requires no voltage adjustment during operation. $1950 f.o.b. factory.

-hp- Model 608A

-hp- Model 610B

-hp- Model 614A

-hp- Model 616A

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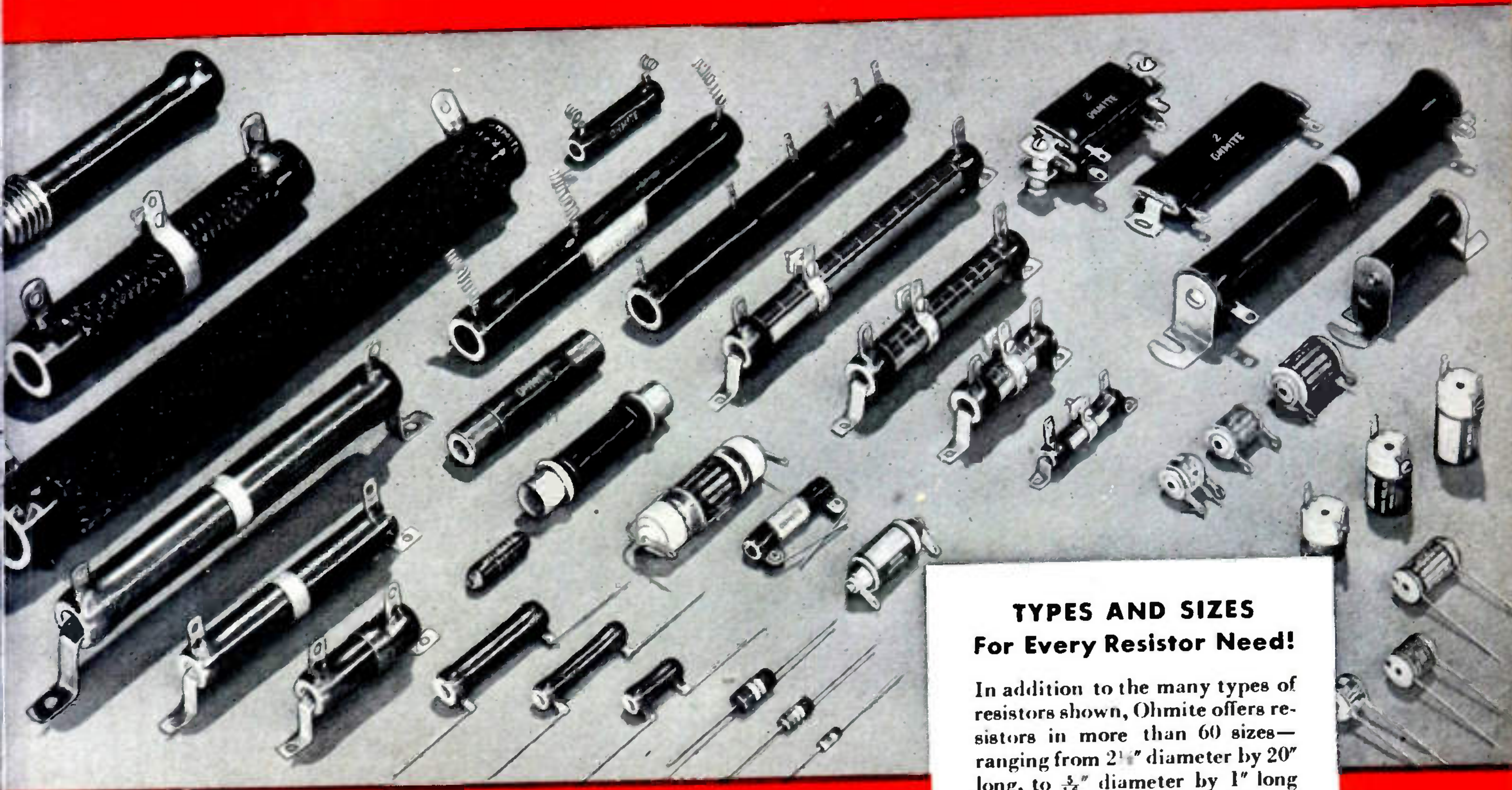

TYPES AND SIZES For Every Resistor Need!

In addition to the many types of resistors shown, Ohmite offers resistors in more than 60 sizes—ranging from $2\frac{1}{4}''$ diameter by 20″ long, to $\frac{5}{16}''$ diameter by 1″ long —to meet your exact requirements. Many sizes are carried in stock.

No matter what your resistor requirements, the chances are that Ohmite has exactly the resistor you need. Ohmite offers fixed, adjustable, tapped, non-inductive, and precision-type resistors in many sizes, types of terminals, and in a wide range of wattage and resistance values. Ohmite application engineers will be pleased to help in the selection of the right resistor for your needs.

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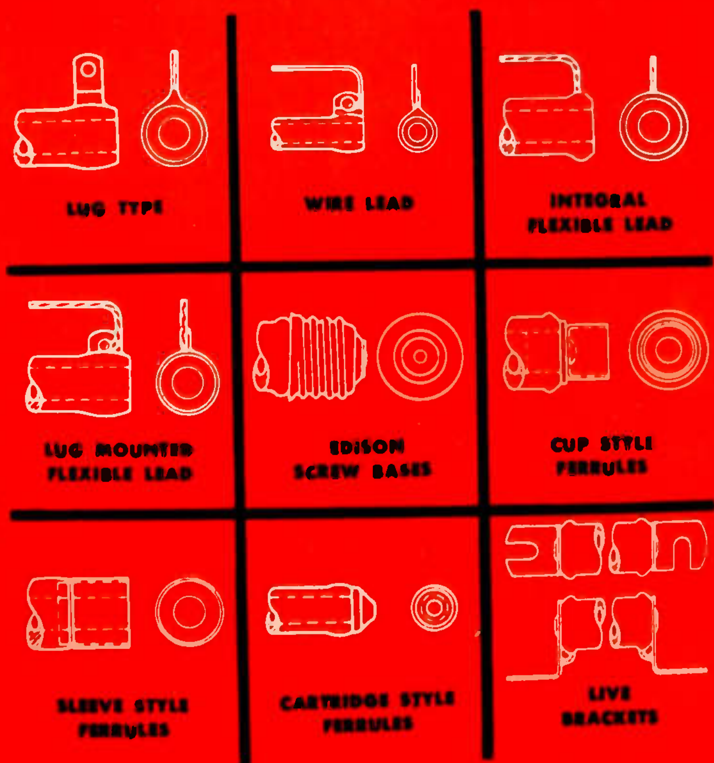

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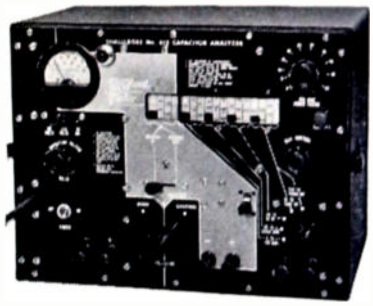
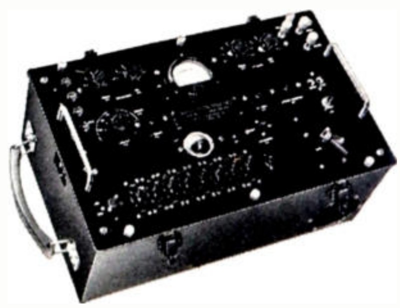


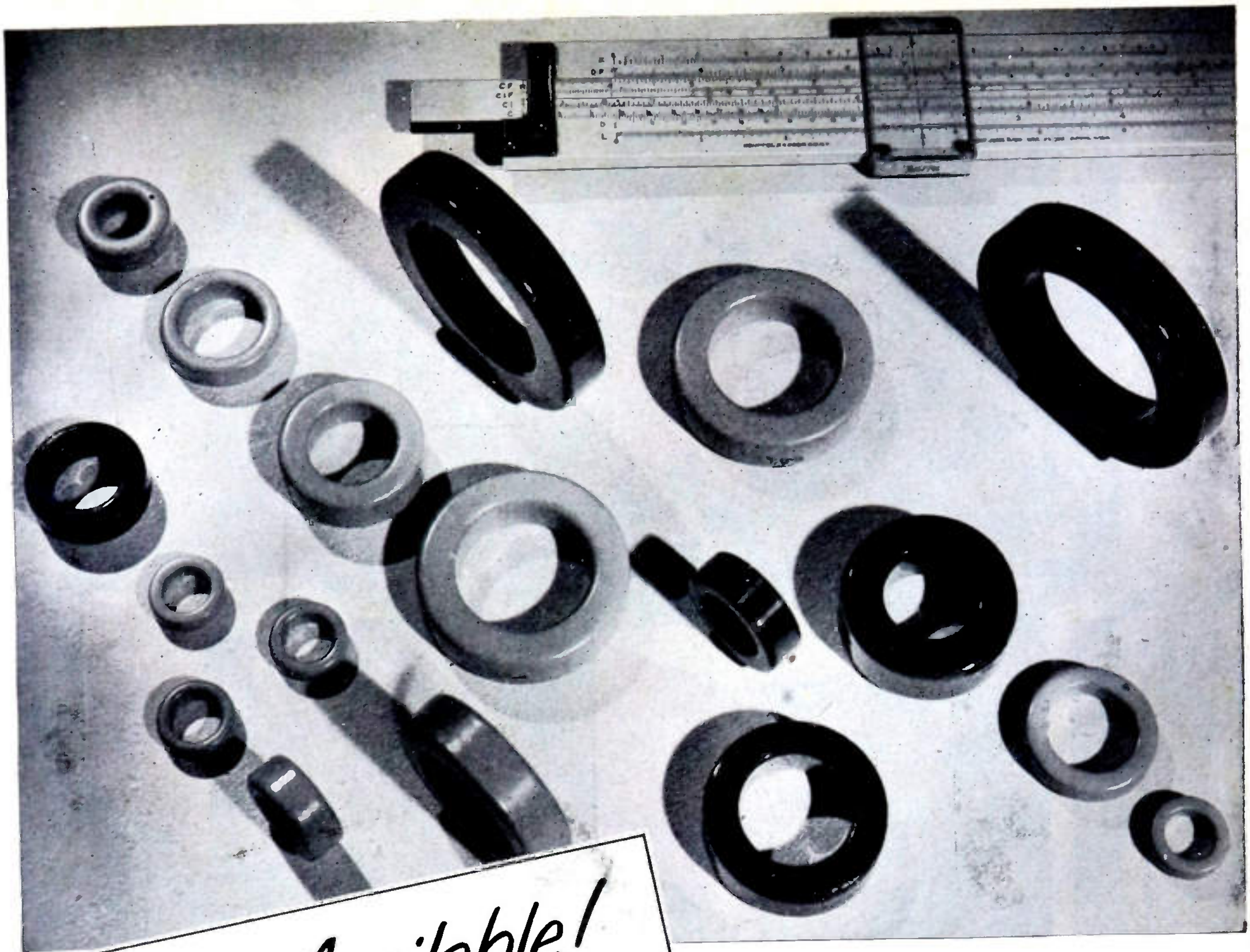
WIDE-RANGE, DIRECT READING CAPACITOR ANALYZER

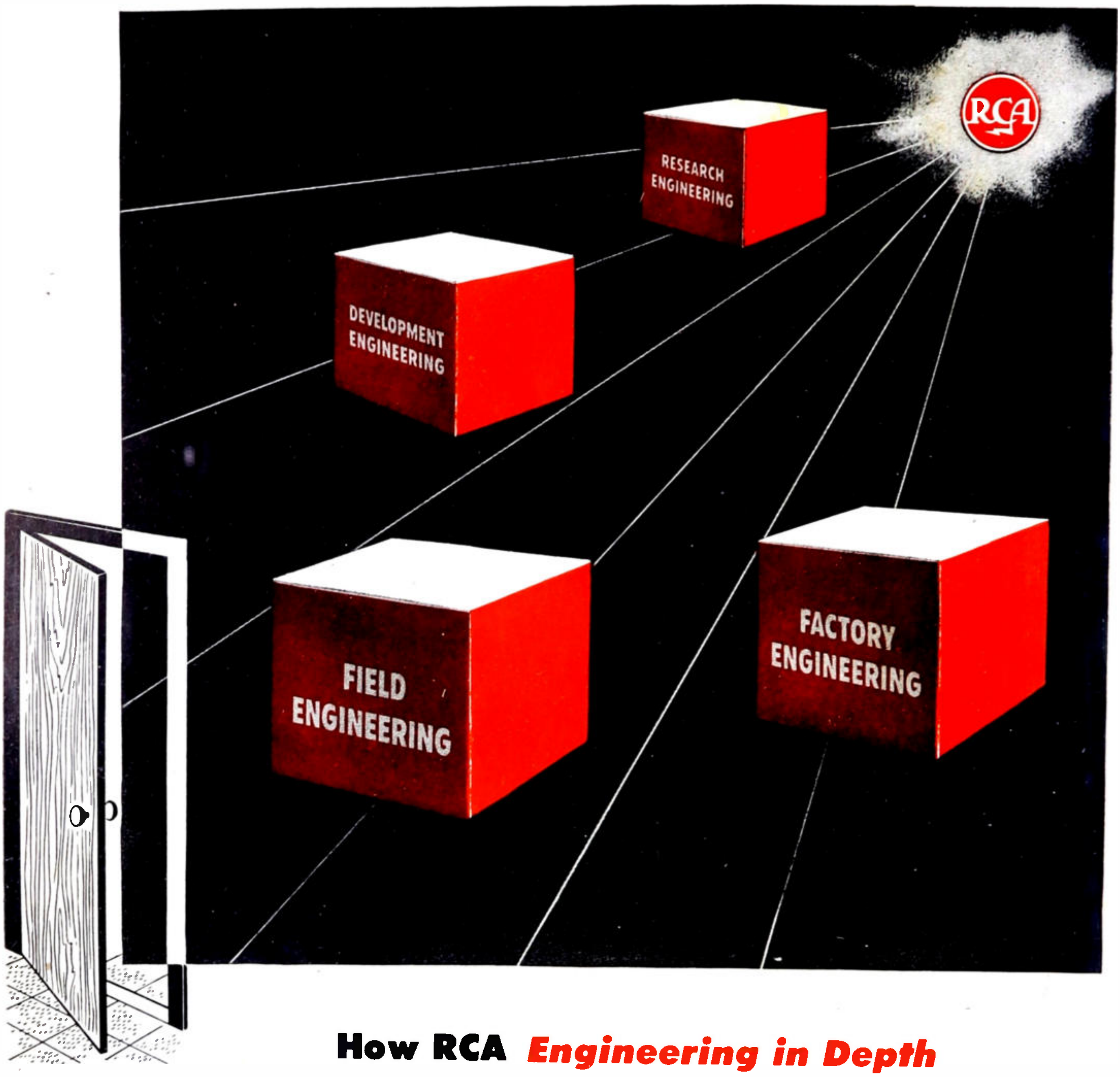
A laboratory-type Capacitor Analyzer meeting the need for a highly accurate, wide-range, direct-reading measuring instrument capable of determining the essential characteristics of capacitors has been announced by the Shallcross Manufacturing Co. This versatile instrument will determine capacitance values between 5mmf. and 12,000 mfd.; insulation resistance from 1.1 to 12,000 megohms; also leakage current, dielectric strength, and percentage power factor. A divided panel carrying an outline of the operating instructions makes it readily possible to use the instrument without reference to an instruction book. The Shallcross analyzer operates on 110 volt, 60-cycle alternating current. Literature giving full details will gladly be sent on request to the Shallcross Manufacturing Company, Collingdale, Pa.



MULTI-PURPOSE TRANSMISSION TEST SET

In addition to measuring the electrical characteristics of telephone lines and equipment the new Shallcross multi-purpose transmission test set may be used for efficiency tests on local and common battery telephone lines and sets, carbon microphones, receivers, and magnetic microphones. It also provides a fast, efficient means of testing capacitors, generators, ringers, insulation resistance, dials, and continuity. Key switches and dials are used to select and control the test circuits. The 693 Transmission Test Set is powered by external batteries. It features compact, substantial construction and is fully portable, thus making it ideal for either field or laboratory use. Details may be obtained from the Shallcross Manufacturing Company, Collingdale, Pennsylvania.

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PROCEEDINGS OF THE I.R.E.

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INSTITUTE NEWS AND RADIO NOTES SECTION

Responsibility for the contents of papers published in the PROCEEDINGS OF THE I.R.E. rests upon the authors. Statements made in papers are not binding on the Institute or its members.

W. R. G. Baker

DIRECTOR, 1950

W. R. G. Baker, vice-president of General Electric Co., Electronics Park, Syracuse, N. Y., and a pioneer in the development of radio and television, was born at Lockport, N. Y. on November 30, 1892. A graduate of Union College with three degrees, Dr. Baker joined General Electric's Research Laboratory in 1917.

His first work on radio included the development and testing of radio apparatus for aircraft, submarines, captive balloons, torpedo boats, destroyers, and battleships. Dr. Baker was later made designing engineer.

In 1924 this responsibility was enlarged to include the design of all radio products, and in 1926, he was given complete charge of development, design, and production. He supervised the design of pioneer broadcasting stations WGY in Schenectady, KOA in Denver, and KGO in Oakland and the Schenectady radio developmental laboratory. The latter aided in maintaining communications with both Byrd Antarctic expeditions.

On the formation of the RCA-Victor Corporation in 1929, Dr. Baker went to Camden, N. J., to head the radio engineering activities of the new organization and was in charge of production and later vice-president of engineering and manufacturing.

In 1935 General Electric transferred its radio receiver activities to Bridgeport, Conn., and Dr. Baker resumed his connections with the Company. He was named managing engineer in 1936, a post he held until May, 1939, when he was promoted to the position of manager of the Company's radio and television department.

In October, 1941, Dr. Baker was elected a vice-president. His department was subsequently redesignated the Electronics Department, now one of the nine GE operating departments, and producer of radio, radar, television and similar equipment in the rapidly expanding electronics industry.

Under Dr. Baker's direction as Chairman of the National Television System Committee the standards for monochrome telecasting were developed, recommended, and adopted by the FCC. As Director of Engineering for the Radio-Television Manufacturers Association, he is actively engaged in co-ordinating the work of the industry on color television.

Under his supervision as chairman of the Radio Technical Planning Board, recommendations for frequency allocations of all broadcasting services were formulated.

Dr. Baker became a member of the Institute in 1919 and a Fellow in 1928. He was President in 1947 and a Director in 1940 and 1946–1950. Dr. Baker was Standards Co-ordinator during 1948 to 1950 and has served on numerous IRE committees.

The inventor of the modern electron tube, and of many other contributions to radio during the last half century, here describes the upward course of radio and offers counsel, based on experience, to his fellow workers of today and to the government officials entrusted with present administrative responsibilities.

The eminent writer of the following guest editorial needs, and can have, no better introduction than to state that he is LEE DE FOREST.—*The Editor.*

A Half Century

LEE DE FOREST

To those of our membership whose professional, or amateur, radio activities span the completed half century, the glance backward from today's eminence of achievement must surely be accompanied by sentiments of wonder and admiration, not unmingled with some nostalgia.

From the crude experiments of Oliver Lodge and Marconi in wireless transmission over the first few miles, when even a wave-meter was unknown, to the spanning of the Atlantic, first with Morse signals, then with the human voice from Arlington to Paris and Honolulu, and on down the years to today's universal network of radio communication of every type and description, shrinking our globe to a mere basketball, the technical progress therein involved defies total comprehension.

With this crowded accomplishment, no organized mental achievement, through the age-long history of the evolving human brain, can successfully compare.

In 1900 our total applicable technical library comprised chiefly the works of Maxwell, Hertz, Tesla, J. J. Thompson, Poincare, and Lodge. The single journals containing an occasional article helpful to the then *Wireless Engineer* were *Wiedemann's Annalen* and the *Philosophical Magazine* of London.

Other than the lone experimenters themselves, few indeed glimpsed at first any commercial future for "Wireless." Even the Army and the Navy saw but small usefulness in our manful efforts, employing alternating current transformers, self-restoring detectors and headphones, to excel the European pioneers with their still more primitive spark-coils, coherers, and tape recorders. Technical progress lagged shamelessly, tightly bound as we then were by the strait limitations of the open spark and arc transmitters. The quenched spark-gap of Max Wien and the electrolytic and crystal detectors were almost the sole instances of progress until entrance upon the scene of the three-element tube with plate supply, first as a far better detector, then as the long-awaited amplifier, poetically foretold forty years before by Professor's Hughes and Stokes—an "hour for which the years (and telephone engineers) did sigh."

As though in apt commemoration of the discovery of that promethean device, the Archimedian electronic lever, destined with feedback to move the world forward, our Institute of Radio Engineers was shortly thereafter established.

Its infant-sized PROCEEDINGS began forthwith to compete with Zenneck's *Jahrbuch der Drahtlos Telegraphie*, and was eagerly welcomed by those to whom German and Greek were essentially synonomous.

The demands and exigencies of World War I forced the swift development of the first watt oscillators into multi-kilowatt types which, with the power-modulation methods of Heising, thereafter made possible huge sponsored earnings by a theretofore virgin-pure radio broadcasting art—a sort of etheric prostitution new to mankind. So broadcasting for hire, like a surging epidemic, spread over the land. What untold tonnages of soap and so-forth were sold therewith; what hosts of otherwise undiscovered "talent" ranged and raged before our inoffensive microphones; what profound changes in our home life, in political destinies were thus unfolded! And what manifold new industries, whose swollen earnings have already totaled more than fifty billions, affording a million new jobs, have we seen founded upon, or grown great from, the electron tube!

Ensued then the regenerative and superhetrodyne receivers, entangled for years in historic patent litigation, even unto the Supreme Court, whereon the patent-lawyer fraternity fattened enormously. Simultaneously during the tumultous 'twenties the amplifying branch of the fast spreading electronic tree blossomed beautifully into sound-on-film, perfected music recording-reproduction, and the oscilloscopic parent of television-realizations of the ancient dreams of Edison and of von Rosing.

Progress during the third decade of our half century may be generally classified as intensified investigation of atmospheric phenomena affecting transmission, the introduction of the electron to industry, rapid development of frequency modulation by Armstrong, and the beginnings of cathode-ray television made possible by the brilliant genius of Zworykin and Farnsworth. Our accumulated store of information and the practical applications thereof added up to immense basic values, forming a firm foundation for what the fighting 'forties were to require.

There the demoniacal demands of World War II, blacking out all cost figures, forced a dozen premature births, such as radar, sonar, the proximity fuze, remote-controlled missles, and the electronic navigational aids that made possible today's congested aviation traffic.

Thus the present status of radio and electronics owes immeasurable debt to the two holocausts that have blackened the fair pages of the history of our first half-century.

Today's astounding public acceptance of television serves as a needed peacetime stimulation to yet swifter, more enobling efforts. Happily there are indications that in (long overdue) time the cultural values beyond all estimation, innate in radio and television, will be realized by those to whom we engineers have had to entrust the commercial applications of the miracles so hopefully created; that eventually the advertiser's profit motive will cease to be the prime factor in the instrumentalities we have been busily introducing into the home-life of America. Assuming that Russia values her peaceful place in the sun, color video, now only nascent, will be our next great contribution to the richness of that home life.

But what in addition to this awaits our world during the ensuing half-century? What further multiple and benign activities await the electron, as undreamed of now as were those of today to the embryonic radio profession of fifty years ago?

These the fortunate chronicler of A.D. 2000 alone can tell.

As we survey the history of modern technological advancement the world over, we find nothing comparable with the past half-century's achievements of American industry, scientifically directed; and nothing in all that vast progress surpassing that of our own radio-electronic structure. Today while our national economy, so often tormented by ill-conceived political restrictions and exactions, presents a rapidly darkening picture, the brilliant record of our special industry and science stands out as a challenging example of the basic virtues of the principle of free enterprise. Let us all therefore highly resolve to keep that proven principle unshackled by the socialistic sophistries which now seek, leech-like, to suck the life blood from our American capitalistic system.

That the record of the next half-century be no less glorious than that of the epoch now ending.

Periodical Literature for Electronic Engineers*

R. C. COILE†

Summary—Periodical literature for electronic and communications engineers has been examined. Suggested lists of periodicals are presented, ranked by relative usefulness for keeping up with current progress and for finding previously published information. Problems of publishing, abstracting, and searching electronic literature are discussed.

Introduction

ELECTRONIC engineers read periodical literature basically for two reasons; first, to keep abreast of current progress, and second, to find previously published information which may help on the particular project on which they are working. In the first instance, one of the problems facing an individual engineer and an academic or industrial library, is the determination of which technical periodicals and/or abstract journals should be read. In the second case, when previously published papers pertinent to a particular project are being searched for, the problems are to determine in which technical periodicals and/or abstract journals to search, as well as in what year to search, and further—how to search.

This paper examines some of the problems of periodical literature for electronic and communications engineers from the reader's point of view. A suggested list of periodicals ranked by relative usefulness is given for browsing and keeping up-to-date activities. Another list of periodicals whose papers have demonstrated more than ephemeral value is given. The time scale and age of published papers pertinent to a particular project have been studied from a probability basis.

Some of the problems of literature search and abstracting are discussed. Work on classification, storing, and handling information for the convenience of the reader is urgently required to cope with the growth of the electronic industry. The size of The Institute of Radio Engineers has been roughly estimated to be 80,000 in 1960 and the PROCEEDINGS OF THE I.R.E. should then be publishing about 800 papers per year.

Periodical Literature for Current Reading

One approach to determining which periodicals are currently publishing papers of interest to electronic engineers would be to examine a large number of current journals for a given period and determine how many pertinent papers on electronic subjects are being published and in which journals. Or instead of examining the journals directly, one might make a statistical study of an abstract journal such as *Science Abstracts* (Section B—*Electrical Engineering Abstracts*), or of the abstracts published in the *Wireless Engineer* and the PROCEEDINGS OF THE I.R.E. The abstract journals exercise a certain amount of selection in choosing which papers their editors consider worthy of abstracting.

A much greater degree of selection is employed by the IRE Annual Review Committee which prepares an annual Report listing the most significant papers published each year. An analysis has, therefore, been made of the recent Report[1] on "Radio Progress during 1949." This IRE committee of 29 members prepared a Report which contained 810 references to 134 periodicals. The report was divided into 22 subject fields with specialists in each field citing the most important papers published in that field in 1949. In passing, one might note that there was no subject field on "measurements"[2] and that only one reference was listed under "industrial electronics."

The periodicals are listed in relative rank in Appendix A, which shows the number of of times the periodical was cited. Fig. 1 illustrates some of these data graphically. Fifty per cent of the references were made to 9 periodicals and 75 per cent were made to 24 periodicals. The last 25 per cent of the references required 110 additional periodicals.

The relative ranking of periodicals given in Appendix A depends, of course, on the subject fields considered. A different selection of subject fields will give a different ranking of journals. Furthermore, it is obvious that the more one restricts one's fields of interest, the fewer journals are pertinent. For example, if one is interested in keeping abreast of progress only in radio-frequency circuits, it is not necessary to read the *Journal of the Acoustical Society*, or the like. However, keeping posted on progress in a single field such as radio propagation requires reading journals in radio, electrical engineering, physics, applied physics, geophysics, and meteorology.

Appendix A, therefore, is suggested as a tentative guide for reading for engineers whose interests lie in the 22 subject fields considered by the IRE Annual Review Committee.

Periodical Literature Used by Electronic and Communications Engineers

The periodical literature actually used by electronic engineers may be determined by studying the footnote references in the technical papers published in the PROCEEDINGS OF THE I.R.E. Presumably these references were of some value to the engineer publishing an account of his own work. A study has been made of these references to determine their sources and ages. Appendix B shows the results of a study[3] made of the 1934 issues of the PROCEEDINGS OF THE I.R.E. The 42 periodicals mentioned in footnote references have been arranged in order of relative rank, with the journals referred to the most times ranked highest.

* Decimal classification: R053. Original manuscript received by the Institute, June 12, 1950; revised manuscript received, July 26, 1950.

† Operations Evaluation Group, Division of Industrial Cooperation, Massachusetts Institute of Technology, Cambridge, Mass.

[1] "Radio Progress During 1949," PROC. I.R.E., vol. 38, pp. 358–390; April, 1950.

[2] An IRE committee on Measurements and Instrumentation was formed during the latter part of 1949 and future Radio Progress Reports will therefore cover the field of measurements.

[3] Charles F. Dalziel, "Journals for electrical engineers," *Elec. Eng.*, vol. 57, pp. 110–113; March 1938.

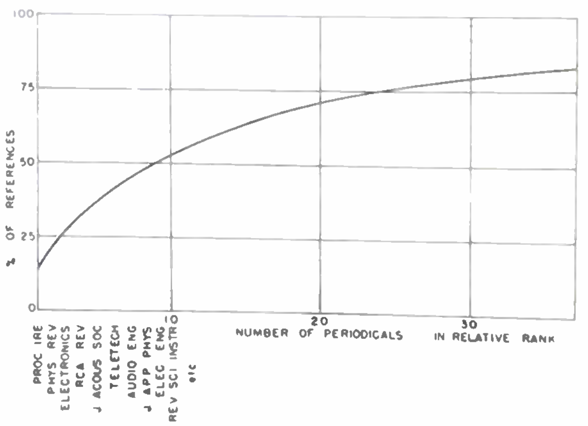

Fig. 1—Sources of reference in IRE Annual Review Report.

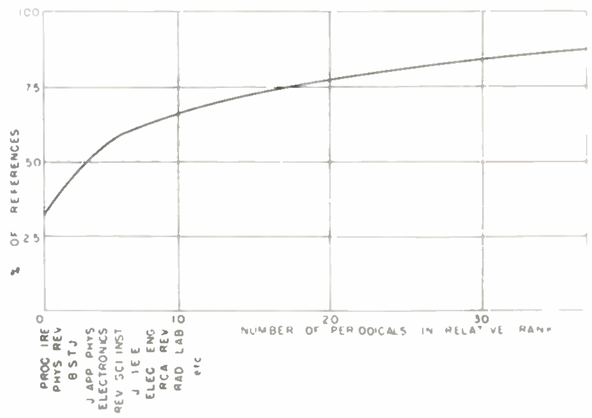

Fig. 2—Sources of references in 1949 PROC. I.R.E.

A study of the 1949 issues of the PROCEEDINGS OF THE I.R.E. is given in Appendix C. One hundred and fifteen periodicals were listed in references. To make this 1949 study comparable with the data for 1934 which excluded periodicals which were not mentioned also by one or more of a selected group of key journals, 73 of these 115 periodicals were determined to be also listed by one or more of the following: *Electrical Engineering, Journal of the Institution of Electrical Engineers, General Electric Review, Electronics*, and *Bell System Technical Journal*. Consequently, 73 periodicals were mentioned in 1949, as compared to 42 in 1934, an increase factor of 1.7. It is interesting to note the gains in relative rank of the *Physical Review, Bell System Technical Journal, Journal of Applied Physics, Electronics, Review of Scientific Instruments*, and *RCA Review*.

Fig. 2 shows graphically the sources of the 1949 IRE references. Fifty per cent of the references came from the first four journals and 75 per cent of the references came from the first 17 periodicals. Then 98 more periodicals accounted for the last 25 per cent of the references.

A study was made of the time interval between the publication year of a paper and its citation as a reference in the 1949 PROCEEDINGS OF THE I.R.E. Fig. 3 shows that 18 per cent of the references were two years old, 16 per cent were one year old, 13 per cent were three years old with decreasing frequency of occurrence for older references. Fig. 4 shows that 50 per cent of the references were less than three years old. Twenty-five per cent of the references were more than nine years old.

These surveys of the 1934 and 1949 issues of the PROCEEDINGS OF THE I.R.E. give an indication of the past use of published literature by engineers in past research programs. The distribution of the sources of the references and the ages of the references depended on the particular research programs reported in the papers. Academic research, for example, may result in a scholarly published paper with more historical footnote references than a paper by an engineer in industry reporting on a current development. It is felt, however, that the listing of periodicals in Appendix C gives an index of usefulness of journals covering the fields of interest to The Institute of Radio Engineers.

LITERATURE SEARCH

The information on sources and ages of references presented in the survey of periodical literature discussed above enables one to start on an "associative trail" type[4] of literature search. Examination of the top ranking five or six periodicals for three or four years back has a fair probability of uncovering papers pertinent to the subject being searched for. Footnote references in these papers furnish leads for further searching. In certain fields, a specialized periodical, e.g., *Journal of the Acoustical Society*, would be the logical place to start a search.

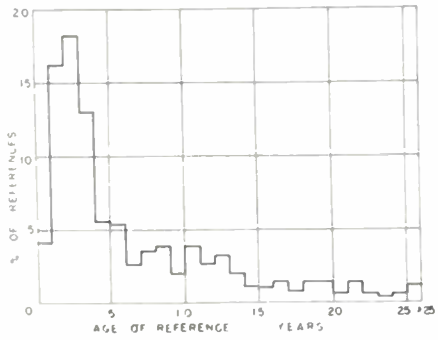

Fig. 3—Distribution of references in 1949 PROC. I.R.E. by age groups.

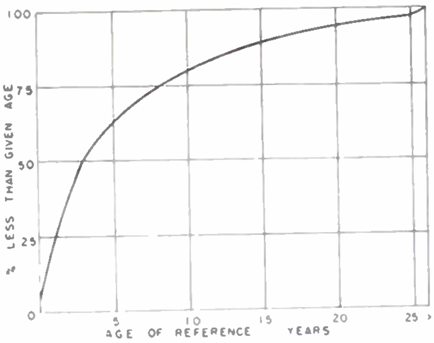

Fig. 4—Age of references.

Abstract journals and abstracting and referencing publications and organizations facilitate an all-out organized search. Some of the abstract and reference publications useful to electronic engineers are the following:

Radio Research Board Abstracts and References (published in the *Wireless Engineer* and reprinted in the PROCEEDINGS OF THE I.R.E.)
Science Abstracts—Section B (*Electrical Engineering* Abstracts)
Mathematical Reviews
References to Contemporary Papers on Acoustics (published in the *Journal of the Acoustical Society of America*.)
Wireless Patents (published in the *Wireless Engineer*)
Review of Acoustical Patents (published in the *Journal of the Acoustical Society of America*)
Engineering Index
Industrial Arts Index
Bibliography of *Scientific and Industrial Reports*
Annales des Telecommunications
Electronic Engineering Master Index
Electronic Engineering Patent Index

The general situation is confusing but it is generally agreed that, despite the large number of different abstracting agencies, many worthwhile papers are being overlooked while others are duplicated in many of the abstract journals.

Probably the most useful for electronic engineers of the above abstracts are those published in the *Wireless Engineer* and PROCEEDINGS OF THE I.R.E. About 80,000 abstracts prepared by the Radio Research Board in England have been published in the *Wireless Engineer* in the past twenty years. The approximate number of these abstracts published each year is given in Fig. 5. Over 4,000 abstracts were published each year for the eight years prior to World War II, with approximately 150 journals scanned.

[4] Vannevar Bush, "As we may think," *Atlantic*, pp. 101–108; July, 1945.

However, the disturbing effect of the breakdown of this abstracting service is indicated by the negative slope of the last four postwar years. In 1948 when 195 journals were scanned, only 3,575 abstracts were published. To have fewer abstracts for a year such as 1948, when thousands more papers were being published than during the war, does not lead to any confidence that a high percentage of pertinent published papers are being abstracted.

A further index of the abstracting activity is given in Fig. 6, where the number of abstracts per year per member of the IRE is shown. The negative slope as well as the small magnitude of this ratio is not encouraging.

When one wishes to use the 80,000 abstracts, one must still face the problem of searching in an annual index or in the 12 issues of the *Wireless Engineer* a year for as many of the past 20 years as desired (a maximum of 240 separate batches of 300 or so references). Some individuals and organizations have the abstracts arranged in card files. This poses the problem of a classification system. The *Wireless Engineer* abstracts had no classification numbers until four years ago when they began to be classified according to the Universal Decimal Classification System. *Electrical Engineering* Abstracts, similarly, had no classification numbers until eight years ago.

At the moment, the systems and aids available for literature search are very crude. It should be possible to mechanize part of the searching with modern electronic techniques. The Departments of Commerce and Agriculture and the Atomic Energy

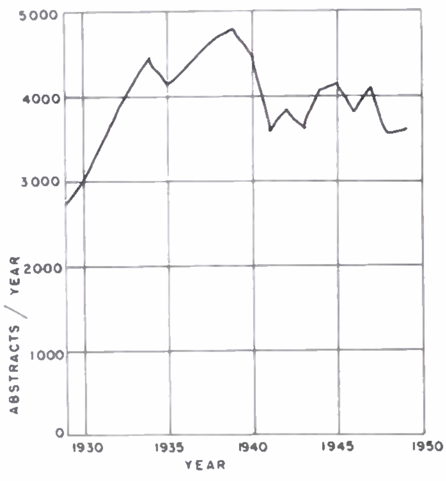

Fig. 5—Abstracts per year in *Wireless Engineer*; now also in PROC. I.R.E.

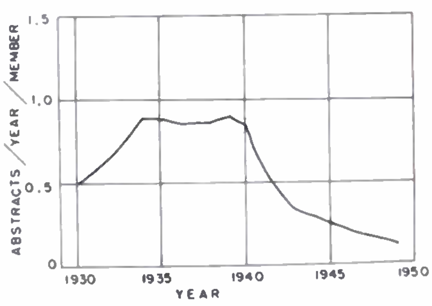

Fig. 6—Abstracts per year per IRE member.

Commission are now experimenting with and developing improved abstract selectors based on the Bush "Rapid Selector" library machine developed at the Massachusetts Institute of Technology in 1938–1940 by John Howard, Laurence Steinhardt, John Coombs, Claude Shannon, and the author.

Documentation

In the past, the problems of documentation have chiefly been the concern of the producers and not the consumers. Publishers and editors have decided publication policy primarily to solve their own problems. Rejecting and/or overcondensing a larger percentage of manuscripts and increasing the delay time between submission of a manuscript and its publication may temporarily solve some of an editor's problems of higher printing costs and increasing volume but are hardly the same solutions a reader would agree with. One alternative[5] under investigation by a professional society suggests that a journal composed solely of brief author abstracts be published at a low subscription rate with inexpensive microfilm copies of any complete paper supplied as desired to a reader.

Libraries are organized principally for the convenience of the librarian and not the reader. The classification systems are organized along medieval lines for the manual practices employed. However, it is encouraging that some groups are worrying about the problems of classifying, storing, and handling information.[6] In addition to the previously mentioned experimentation with microfilm abstract machines by the Departments of Commerce and Agriculture and the Atomic Energy Commission, other groups, such as the Center for Scientific Aids to Learning at the Massachusetts Institute of Technology, are working on documentation problems. Another approach is being made by the American Chemical Society[7] which is working with a manufacturer of punched-card business machines to have a machine designed for nonnumerical purposes, since more than one million Chemical Abstracts have already been published.

One of the problems facing electronic engineers is the publication of an increasing volume of reports on current research. Dr. Vannevar Bush has estimated that since the war scientific research has increased by a factor of at least 10. The growth of the electronic industry and its requirements for publication need examination for planning the attack on the problems of the writer, the editor, the librarian, and the reader. Some preliminary estimates will be given to stimulate further investigation.

Number of Electronic and Communications Engineers

An index of the growth of electronic and communications industry may be obtained from consideration of the membership of The Institute of Radio Engineers. The IRE was formed in 1913 and has grown as illustrated in Fig. 7. It will be seen that the trend of increasing membership would indicate a possible 47,000 in 1955, and a possible 80,000 in 1960. This assumes that no new national engineering societies will be formed which would absorb large numbers of the new electronic engineers who may not be specialists in "radio," and that The Institute of Radio Engineers continues its broad interests in electronics.

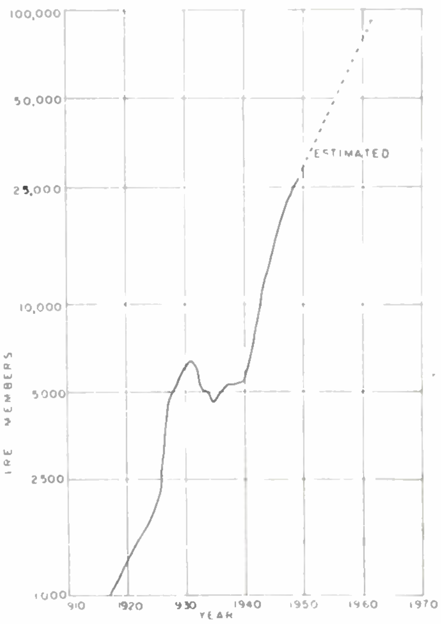

Fig. 7—IRE membership.

Proceedings of the I.R.E.

The Institute of Radio Engineers has had a publication from the time of its origin thirty-seven years ago. Fig. 8 shows the number of papers published per year in the Proceedings. Over 100 papers have been published each year since 1927, with the exceptions of one depression year and two World War II years. The number of "papers" includes book reviews which have been numerous in postwar years. For example, in 1948, of the total of 266 papers shown in Fig. 8, 173 were original technical papers and 93 were book reviews. The over all figures have been used, as it is considered that both papers and book reviews need consideration in keeping abreast of the field.

During the war years when publication was curtailed, the Institute made plans and set aside special funds for large postwar publication of papers when the easing of security restrictions and paper restrictions permitted. Fig. 8 shows the marked increase in papers published in the postwar years. However, this increase has covered the deficit of the war years when many papers were not published which would have been published in normal times—if one is talking about a static condition. But the Institute is dynamic and has more than quadrupled its membership since 1940. The ratio of papers published per year per IRE member given in Fig. 9 shows the trend from 1914 to date and the projected trend which gives an estimate of 0.01 paper per year per member in 1960. If this trend is considered reasonable, the estimates of the growth of the IRE given previously would indicate that the size of the Proceedings in 1955 should be at least 550 papers, and 800 papers in 1960.

Acknowledgment

This paper is part of a preliminary study of the problems of documentation in electrical engineering literature being carried out in the Vail Library of the Massachusetts Institute of Technology. The author wishes to express his appreciation to Ruth McGlashan Lane, Vail Librarian, and Samuel H. Caldwell for helpful suggestions and encouragement.

The author further wishes to express his appreciation to Harold L. Hazen who suggested the investigation, and to Vernon D. Tate and James W. Perry for their interest and helpful discussions.

[5] Vernon D. Tate, "An Appraisal of Microfilm," presented, the American Chemical Society Meeting, Atlantic City, N. J., September 20, 1949.

[6] Royal Society Scientific Information Conference Report, London, 1948.

[7] J. W. Perry, "The A.C.S. Punched Card Committee," *Chemical and Engineering News*, vol. 27, pp. 754–756; March 14, 1949.

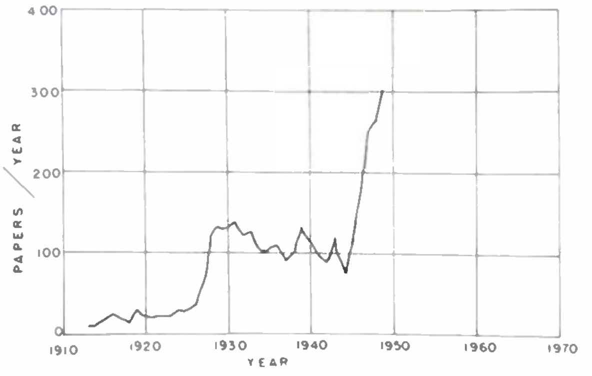

Fig. 8—Papers in Proc. I.R.E. per year.

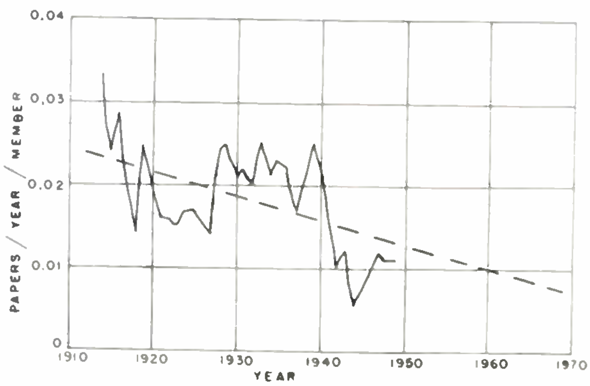

Fig. 9—IRE papers per year per member.

Appendix A

Periodicals for Current Reading in Electronic and Communications Engineering[1]

Relative Rank	Periodical	Number of Citations
1	PROCEEDINGS I.R.E.	118
2	*Physical Review*	57
3	*Electronics*	56
4	*RCA Review*	36
5	*Journal Acoustical Society of America*	32
6	*Tele-Tech*	31
7	*Audio Engineering*	28
8	*Journal Applied Physics*	27
9	*Electrical Engineering* (and *Transactions of AIEE*)	24
10	*Review of Scientific Instruments*	20
11	*Bell System Technical Journal*	19
12	*Journal Society Motion Picture Engineering*	18
13	*Digital Computer Newsletter*	17
14	*Wireless Engineer*	17
15	*Journal Institution of Electrical Engineers*	14
16	*Nature*	13
17	*Proceedings National Electronics Conference*	13
18	*L'Onde Electrique*	12
19	*Nucleonics*	12
20	*Communications*	11
21	*FM and Television*	11
22	*Compes Rendus Academy of Science (Paris)*	9
23	*Philips Technical Review*	9
24	*Bell Laboratories Record*	8
25	*Proceedings Physical Society*	7
26	*Technical Information Pilot*	7
27	Papers presented at AIEE Summer Meeting	5
28	Math Tables and Other Aids to Computation	5
29	*RMA Standards*	5
30	*A. E. U.*	4
31	Papers presented at AIEE Winter Meeting	4
32	*Electrical Communication*	4
33	*Journal Geophysical Research*	4
34	*Journal Scientific Instruments*	4
35	*Radio Television News*	4
36	*Railway Signaling and Communication*	4
37	*Telephone and Telegraph Age*	4
38	*The Engineer*	4
39	*Wireless World*	4
40	*American Standards Association*	3
41	*Ann. Radio Elec.*	3
42	*Electronic Engineering*	3
43	Papers presented at the IRE National Convention	3
44	*Observatory*	3
45	*Philips Research Reports*	3
46	*Proceedings Royal Society A*	3
47	*Western Union Tech. Rev.*	3
48	*Annual Telecommunications*	2
49	*Arch. Elek. Uebertragung*	2
50	*Astro. Journal*	2
51	*Bulletin Academy of Science (USSR)*	2
52	*Bulletin Assoc. Suisse Elec.*	2
53	*Engineering*	2
54	*Frequency*	2
55	*General Electric Review*	2
56	Papers presented at IRE Fall Meeting	2
57	*Journal Laboratory and Clinical Medicine*	2
58	*Journal Phys. Radium* (France)	2
59	MIT Research Laboratory of Electronics	2
60	*Naturwiss*	2
61	*Optik*	2
62	*Philosophical Magazine*	2
63	*Proceedings Indian Academy of Science*	2
64	*Sky and Telescope*	2
65	*Trans. Chalmers University of Technology*	2
66	*Acta Crystallographica*	1
67	*Advanc. Science*	1
68	*Agricultural Engineering*	1
69	AIEE-IRE Theory of Communication Lectures	1
70	*Alta Frequenza*	1
71	*American Mineralogist*	1
72	*Appl. Scientific Research*	1
73	*Ark. Mat. Astro. Fys.*	1
74	*Aust. Journal Scientific Research*	1
75	*Automat i Telemakh* (Russia)	1
76	*BBC Quarterly*	1
77	*British IRE*	1
78	*British Journal of Psych.*	1
79	Brush Dev. Co. *Quarterly Report*	1
80	*CRPL Report*	1
81	*Discussion of Faraday Soc.*	1
82	*Edison Electric Inst. Bulletin*	1
83	*Elec. Review* (London)	1
84	*Elek. Wiss. Tech.*	1
85	*Endeavour*	1
86	*Engineer*	1
87	*Fernmeldtech Z.*	1
88	*Federal Engineer*	1
89	*FIAT Review of German Science*	1
90	*Fortune*	1
91	*GEC Journal*	1
92	*Gen. Radio Tech. Pub.*	1
93	*Helv. Phys. Acta*	1
94	*HF (Brussels)*	1
95	*Indian Journal Phys.*	1
96	*Institute of Navigation*	1
97	*IBM Publication*	1
98	*Journal British Astro Association*	1
99	*Journal Chem. Phys.*	1
100	*Journal Electro Chem. Society*	1
101	*Journal Franklin Inst.*	1
102	*Journal Ind. Hygiene and Toxicology*	1
103	*Journal of Metals*	1
104	*Journal of Met.*	1
105	*Journal Optical Society of America*	1
106	*Journal Res. National Bureau Standards*	1
107	*Journal Royal Astro Society, Canada*	1
108	*Journal Tech. Phys.* (USSR)	1
109	*Kungl Tekn Hogsk Handl* (Stockholm)	1
110	*Marconi Review*	1
111	*Nuovo Cim*	1
112	*Physics Today*	1
113	*Proceedings IRE* (Australia)	1
114	*Quarterly Appl. Math.*	1
115	*Quarterly Journal Royal Met. Society*	1
116	*Radio Franç.*	1
117	*Radio Tech Dig* (France)	1
118	*Ry. Age*	1
119	*Radiotronics*	1
120	*Review Gen. Elec.*	1
121	Chalmers University of Technology Research Laboratory of Electronics	1
122	*Science Monthly*	1
123	*Tech. Bulletin National Bureau Standards*	1
124	*The Quill*	1
125	*Toute la Radio*	1
126	*Trans. American Geophys. Union.*	1
127	*Trans. American Society Mechanical Engineers*	1
128	*Trans. S. Afr. Inst. Electrical Engineering*	1
129	*University of Kentucky Report*	1
130	Wesleyan University Report to Sig C	1
131	Williams College Meeting American Phys. Society	1
132	*Zeits. Angew. (Phys.)*	1
133	*Zh. Tekh. Fiz.* (Russia)	1
134	*Zeit. Ver dtsch. Ing.* (VDI)	1

Appendix B

Periodicals Used by Electronic and Communications Engineers in 1934

Relative Rank	Periodical	Number of Citations
1	PROCEEDINGS OF THE I.R.E.	(180)
2	*Wireless Engineer*	37
3	*Bureau Standards Journal of Research*	31
4	*Philosophical Magazine*	30
5	*Nature*	30
6	*Physical Review*	23
7	*Bell System Technical Journal*	20
8	*Proceedings Physical Society*	20

APPENDIX B—(*continued*)

Relative Rank	Periodical	Number of Citations
9	*Proceedings Royal Society*	20
10	*Zeitschrift fur Technische Physik*	19
11	*Annalen der Physik*	18
12	*Comptes Rendus*	17
13	*Elektrische Nachrichten Technik*	16
14	*Zeitschrift fur Physik*	15
15	*Journal Acoustical Society*	15
16	*Journal Institution of Electrical Engineers*	14
17	*Hochfrequenztechnik und Elektroakustik*	10
18	*Archiv fur Elektrotechnik*	10
19	*Electronics*	9
20	*Wireless World*	8
21	*Physikalische Zeitschrift*	7
22	*Telefunken-zeiturg*	7
23	*Journal Institution of Electrical Eng. of Japan*	6
24	*Radio Engineering*	6
25	*L'Onde electrique*	5
26	*Annales des Postes, Telegraphes et Telephones*	5
27	*Electrical Engineering*	4
28	*Helvitica Physica Acta*	3
29	*Alta Frequenza*	3
30	*Electrician*	3
31	*Physics*	3
32	*Electrotechnische Zeitschrift*	2
33	*Physica*	2
34	*Journal Franklin Institute*	2
35	*Journal Scientific Instruments*	2
36	*Journal Society Motion Picture Eng.*	2
37	*Astrophysical Journal*	1
38	*Electrical Communication*	1
39	*Trans. Optical Society*	1
40	*Review of Scientific Instruments*	1
41	*Electrical World*	1
42	*General Electric Review*	1

APPENDIX C

PERIODICALS USED BY ELECTRONIC AND COMMUNICATIONS ENGINEERS IN 1949

Relative Rank	Periodical	Number of Citations
1	PROCEEDINGS OF THE I.R.E.	(262)
2	*Physical Review*	56
3	*Bell System Technical Journal*	51
4	*Journal Applied Physics*	47
5	*Electronics*	34
6	*Review Scientific Instruments*	26
7	*Journal IEE*	22
8	*Electrical Engineering*	16
9	*RCA Review*	15
10	*Rad. Laboratory Reports*	13
11	*Cruft Laboratory Reports*	11
12	*Nature*	11
13	*Wireless Engineer*	11
14	*Electrical Communications*	9
15	*Philosophical Magazine*	9
16	*Proceedings Royal Society*	8
17	*Journal Franklin Institute*	7
18	*Communications*	6
19	*General Rad. Experimenter*	6
20	*Journal Acoustical Society of America*	6
21	*Journal Society Motion Picture Engineers*	6
22	*Proceedings Phys. Society*	6
23	*Proceedings Nat. Electronics Conference*	6
24	*Research Lab. of Electronics*	6
25	*Tele-Tech.*	6
26	*Zeit. fur Phys.*	5
27	*Archiv. fur Elek.*	5
28	*Bulletin American Meteorological Society*	5
29	*Helv. Phys. Acta*	5
30	*Ind. Eng. Chem.*	5
31	*Phys. Zeit.*	5
32	*Review Mod. Physics*	5
33	*University Texas E. E. Research Lab.*	5
34	*Journal Math. Phys.*	4
35	*Journal Optical Society of America*	4
36	*Physica*	4
37	*Annales der Phys.*	3
38	*Bell Laboratory Research*	3
39	*Elek. Nach. Tech.*	3
40	MDDC	3
41	*Proceedings American Philosophical Society*	3
42	*Science*	3
43	*American Journal Physics*	2
44	*Chalmers Tek.*	2
45	*Comptes Rendus*	2
46	*Doklady Academy Science Ukraine*	2
47	*Electrical Journal*	2
48	*Funk und Ton*	2
49	*Food Ind.*	2
50	*Hochfrequenza und Elektroak.*	2
51	*Journal General Physiology*	2
52	*Journal Research National Bureau Standards*	2
53	*Journal Scientific Instruments*	2
54	*Leiden Comm.*	2
55	*Nucleonics*	2
56	*Oak Ridge Nat. Lab.*	2
57	*Philips Research Reports*	2
58	*Physics*	2
59	*Proceedings Cam. Philosophical Society*	2
60	*Quarterly Applied Mathematics*	2
61	*Review Gen. Elec.*	2
62	*Zeit Phys.*	2
63	*Z. Naturf.*	2
64	*American Math. Society Bulletin*	1
65	*Annales de Telecommunications*	1
66	*Annales Radio-elec.*	1
67	*Anal. Chem.*	1
68	*American Journal Roentgenology and Rad. Therapy*	1
69	*Bell Tel. Quarterly*	1
70	*British Journal Radiology*	1
71	*Brooklyn Polytechnic Inst.*	1
72	*Bulletin Soc. Franç. Elec.*	1
73	*Bulletin Academy Royal Belgique*	1
74	*Bureau Standards Scientific Papers*	1
75	*Camp Evans Signal Lab. Report*	1
76	*Chemical and Engineering News*	1
77	*Chem. and Ind.*	1
78	*Das Electron*	1
79	*Elec. Ind.*	1
80	*Electronic Eng.*	1
81	*Stanford U. Electronics Research Lab.*	1
82	*AMC Electronics Research Lab.*	1
83	*Geophys. Publik.*	1
84	*Ind. Radiography*	1
85	*Journal Aero Science*	1
86	*Journal American Chemical Society*	1
87	*Journal Applied Mech.*	1
88	*Journal British Inst. Rad. Eng.*	1
89	*Journal Chem. Phys.*	1
90	*Journal Phys. and Colloid Chemistry*	1
91	*Journal Phys. Chem.*	1
92	*Journal Phys.* (URSS)	1
93	*Journal Phys. Radium*	1
94	*Journal Royal A, Society Cam.*	1
95	*L'Onde Elec.*	1
96	*Luftfohrforschung*	1
97	*Naturwissenschaften*	1
98	*Nova Acta Royal Society Science (Uppsala)*	1
99	*Phil. Tech. Review*	1
100	*Proceedings Nat. Academy Science*	1
101	*Product Eng.*	1
102	*Radio*	1
103	*Radio Research Board*	1
104	*Science Monthly*	1
105	*Stanford U. Micro-Wave Lab.*	1
106	*Tech. Mitt. Jg.*	1
107	*Terr. Mag. Atmo. Elec.*	1
108	*The Oscillator*	1
109	*TRE*	1
110	*U. S. AEC Report*	1
111	*Wissenschaften Aero, Siemens*	1
112	*Westinghouse Eng.*	1
113	*Wireless World*	1
114	*Zeit. Tech. Phys.*	1
115	*VDI Zeitschrift*	1

Practical Design for Effective Production and High Quality*

JOSEPH MANUELE†

The following paper has been made available for publication through the good offices of the IRE Professional Group on Quality Control, and has received the approval of that Group.

Summary—**Every newly developed appliance must pass through three stages before finally reaching the home; namely, the laboratory model stage, the engineering model stage, and the mass production stage. The engineering model stage is really the "pilot plant" stage of production where the laboratory model is proved and the manufacturing "bugs" are worked out before placing the article in mass production.**

The engineering model stage of manufacture is controlled most effectively by the verification committee whose function it is to prove that component parts as well as the article itself can be, or cannot be, manufactured with the existing equipment and personnel. The verification committee proves that the engineering department has really come up with a good idea which is practical and which can be manufactured economically and in quantities. The verification committee also points out weaknesses in design.

The verification committee is guided in its analyses and recommendations by the principles governing practical design for effective production and high quality, which are: (1) simplicity of design, (2) minimum number of component parts, (3) clearly defined and measurable quality standards, and (4) absolute interchangeability of parts.

HISTORY RECORDS that in the late 1790's Eli Whitney was granted a contract from the United States government to make some muskets. In those days muskets were made by trained artisans, and each musket was as good as the skill of the individual worker could make it. Presumably if a gun were damaged in battle action, a soldier could not take parts from another damaged gun to repair his own. There was no recognition of the principle of "interchangeability of parts" in those days. Neither was the importance of designing for effective production recognized, and product quality reflected a combination of the worker's skill and pride in his job.

But Eli Whitney was a shrewd industrialist. He recognized the importance of design for effective production, and of the value of the principle of interchangeability of parts. He could do nothing about the design of the muskets, since this was already fixed, but before he started production, he made a set of gages for the various parts. Then he made the parts to the gages. Hence, every part could be assembled into its proper place on any musket, and the musket would function perfectly. History does not record whether there was a renegotiation on the contract, but we suspect that Mr. Whitney made a satisfactory profit on the transaction because of the cost reduction effected by his simplification in manufacturing method.

This incident really marks the beginning of modern "straight line" manufacturing techniques. These mass production methods are responsible for having made America great, and for having provided Americans with more comforts and more leisure than some of us are able to use wisely.

However, the art and science of product design to facilitate mass production has not always kept pace with progress in manufacturing methods. When contemplating a new design, how often have we heard the remark, "But can it be mass produced?" Because of the tremendously large and profitable American market, competition to reach that market is intensely keen. Hence, products intended for the American home must be mass-produced, if they are to be profitable.

Every newly developed home appliance usually goes through three stages before finally finding its place in the American home as a necessity, or even a luxury, of everyday living: (1) laboratory model stage, (2) engineering model stage, and (3) mass-production stage.

After the product has germinated in the mind of the inventor, the first stage it must pass through is the laboratory model stage. Here some of the theoretical principles of its operation are proved, modified or discarded. The main interest here is "Will it work?" Has the inventor really produced something of practical value, or has he just "laid an egg"? This laboratory model stage is very important because every year the ingenious mind of man creates many new products, some of which are just plain duds, and some of which can be termed only as scientific curiosities. Obviously industrial capital cannot be risked on duds, or scientific curiosities, manufactured by the million. Hence such new creations must be proved in the laboratory.

After the product has passed successfully through the laboratory model stage and it has been definitely proved that a product of some practical value has been developed, it is put through the engineering model stage. Here, the aim is to adapt the new product for profitable mass production. Changes in engineering design are made, if required to facilitate production in quantities. The various "bugs" are taken out of it, and the product is streamlined for "tooling." It is at this

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stage that tool-made samples are produced to prove tools, production methods, and the product itself. Costs of production also are estimated at this point, and a sufficient number of units are manufactured and made available to the quality control department for a thorough "quality analysis" of the product.

Because of difficulties in meeting quality standards, or because of manufacturing problems which cannot be resolved, some products never get beyond this engineering model stage, and they are "put on the shelf," or "killed," at this time. Sometimes they are sent back to the engineering department with suggestions for redesign, and are later brought back through the engineering development stage a second time.

During this period of engineering development the *verification committee*, of the quality control department makes its quality analysis of "production method" produced samples, and gives its recommendations on whether the product: (1) comes up to proper quality standards, and (2) whether the design of component parts, and the product as a whole, lends itself to economical mass production with the available tools and personnel.

In order to make this quality analysis, a few units of the new product are manufactured, as nearly as possible, under production conditions, and these units are turned over to the quality control department for inspection and test in the regular way. No special inspection or test procedures are used at this point, and no special concessions are made in regard to product quality. The product is judged against the engineering quality standards which have been established, even though these standards may be tentative at this time.

Each part, component, and the completely assembled product, is inspected and tested, and a note is made of the *actual quality* and the *desired quality*. From this information a report is prepared, on regularly prepared forms, and submitted to the verification committee.

The function of the verification committee is twofold: to determine whether the product is of such quality that it will give the minimum amount of trouble in the field, from both the functional and aesthetic point of view; and whether the product and its various components can be mass-produced with the available manufacturing facilities and personnel.

The verification committee consists of an authorized representative from each of the following: (1) manager of quality control, (2) superintendent of manufacturing, (3) manager of engineering, (4) manager of sales, and (5) purchasing agent.

The product and its components are kept in the engineering development stage, and released for regular production only after the verification committee has given its approval. The verification committee may recommend design changes to facilitate mass production, and it may also recommend changes in manufacturing methods, or tools, if this appears desirable. The object is to take the "bugs" out of the product so that, when it is put in production, no major production difficulties will be encountered.

When a product gets into production it is subjected to the strictest kind of inspection and testing in order to evaluate its functional qualities, and unless it meets well-defined, and often rather narrow, quality standards, rejections may be rather high and costly. Furthermore, a product in the production stage must move rather smoothly along the processing line. It is desirable that it lend itself to manufacturing and assembly by relatively unskilled labor, since skilled labor is generally scarce and costly.

It is during this engineering development stage that the design of the product is really tested for effective production and high product quality. Practical design for effective mass production requires absolute interchangeability of parts. These parts must be interchanged without the necessity of "fitting at assembly," or "adjusting at test." It is true that this ideal is "approached" more frequently than it is "achieved." However, it is when this ideal of absolute interchangeability is achieved that profits are highest, and product quality is most satisfactory.

To achieve this ideal of absolute interchangeability it is necessary that component parts be made to clearly defined and measurable quality standards. These quality standards must provide for sufficient variability to permit economical manufacturing, and yet this variability must be within sufficiently narrow limits to allow the part to operate satisfactorily in the completed unit, without the need of fitting at assembly, or adjusting at test.

These adjustments at assembly mean higher manufacturing costs and somewhat less uniform, though in some cases, better quality. Adjustments made in this manner are subject to the skill of the tester, and no two testers work exactly alike; nor do they possess the same skill and judgment. Furthermore, since these testers generally require training for some period of time, their labor rates are higher. Therefore, the aim, when designing for effective mass production, should be to:

(1) Simplify the design of component parts and the product, so that all operations may be performed by relatively unskilled operators.

(2) Establish such quality standards for component parts as will make the achievement of interchangeability a practical reality.

(3) Reduce the number of component parts to a minimum. This will reduce the cost of component parts required, and the cost of the assembly operation.

(4) Make effective use of the verification committee to make a proper quality analysis of the product, to prove the design for effective production and satisfactory quality.

But assuming that all of these four steps have been taken and the new product has passed satisfactorily through the laboratory model stage and the engineering model stage, and it has been given the proper approval for regular production by the verification committee, it does not necessarily follow that the production stage will be free of all difficulties, regarding either production, or quality. Production bottle-necks will be encountered, and it will be found difficult to maintain proper quality standards under the usual press for production. Pertinent and accurate information must be carried back to the design engineers so that designs can be altered to facilitate production in order to break production bottlenecks, or to improve quality, if it is felt that design changes will achieve these aims.

However, design changes during the production stage are costly; they interfere with production, and they require additional expenditures for tools. Therefore, these must be kept at a minimum. In many cases it has been found advantageous to "freeze" designs for a definite period. During this period, all desired changes are accumulated. Then at the end of the specified period, all accumulated changes are made in one major redesign of the product. Of course this procedure cannot be followed if difficulties are of such a nature as to interfere with production, or if quality is so poor as to result in excessive field trouble, or in a possible dropping off of customer acceptance of the product.

In order that correct and useable information might be had on the success of the product in passing through the production stage, it is necessary that adequate records be accumulated by the shop. The quality-control charts kept by the quality control department will generally be found satisfactory for this purpose. Every design engineer should review, critically, these quality-control charts, at least weekly. He should study these charts from two points of view: (1) Is the quality which he established for his product being properly maintained? and (2) If the shop is having trouble achieving a proper level of quality, can he redesign or modify the product to make this attainment easier?

The design engineer's responsibility for his product does not end when the product has been placed in production, although many engineers seem to think so. Design engineers can acquire a liberal engineering education from shop operatives who fabricate the product. "Simplicity of design" is a phrase which covers a vast engineering territory, but it is a goal more held in the breach than in the observance. The design engineer, therefore, will do well to spend some time "on the floor," at least several times each week, to note how well his brain child is thriving on the rough fare the shop personnel is able to feed it. High rejections and high manufacturing costs may not always be due to poor manufacturing methods.

In summing up, it can be said that the good design engineer who wishes to produce a practical product design for effective production and high quality, must keep uppermost in his mind: (1) simplicity of design, (2) minimum number of component parts, (3) clearly defined and measurable quality standards, and (4) absolute interchangeability of parts.

Graphical Analysis of Transistor Characteristics*

LLOYD P. HUNTER†

Summary—**Graphical constructions are given which will determine the circuit constants necessary for the design of voltage amplifiers, current amplifiers, and oscillators, from the dc characteristics of the transistors to be used.**

SEVERAL papers[1,2] have been published analyzing the characteristics of transistors from the point of view of equivalent circuits. These analyses are quite cumbersome to apply to the typical transistor since its characteristics change so much over its range of operation that no simple equivalent circuit can be set up to give its full behavior, and the constants of a simple equivalent circuit must be re-evaluated at each new operating point. If a graphical method is used, however the analysis will apply to all parts of the operating range of a given transistor and will lead to a visualization of the type of transistor characteristic that will do a given job. The purpose of this paper is to demonstrate such a graphical method.

Perhaps the most striking difference between a transistor and a conventional vacuum triode is that in the tube there is no reaction of the plate circuit upon the grid circuit, while in the transistor the emitter characteristics are greatly modified by the collector circuit. This means that the behavior of a transistor must be deduced from two sets of volt-ampere characteristics rather than one. The two sets of volt-ampere characteristics used here are those of the emitter and the collector, rather than two sets of some sort of mutual characteristics. These characteristics suffice to show the basic relations involved and are the two sets most easily and naturally measured.

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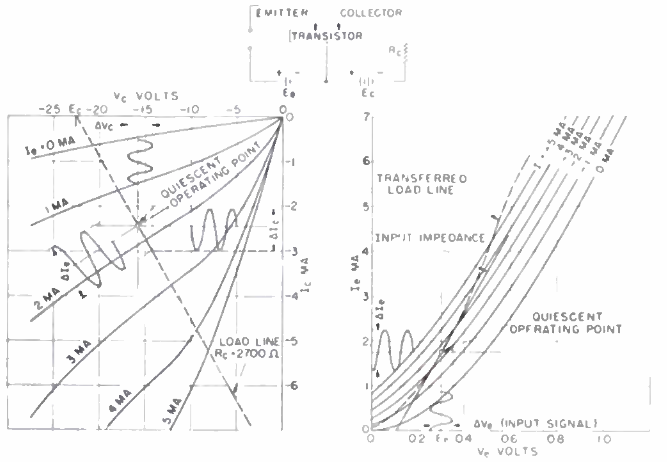
[1] R. M. Ryder and R. J. Kircher, "Some circuit aspects of the transistor," *Bell Sys. Tech. Jour.*, vol. 28, p. 367; July, 1949.

[2] W. M. Webster, E. Eberhard, and L. E. Barton, "Some novel circuits for the three-terminal semiconductor amplifier," *RCA Rev.*, vol. 10, pp. 5–17; March, 1949.

In Fig. 1 are shown the volt-ampere characteristics for both the collector (output) and emitter (input) sides of a typical transistor, connected as shown. The circuit is that of a simple voltage amplifier. If a load line R_c is drawn in the collector (output characteristic) plane and is transferred point by point to the emitter (input characteristic) plane, the quiescent operating point will be the intersection of this line with the ordinate erected at $V_e=E_e$, the emitter bias supply voltage. The input impedance will then be given by the slope of this transferred load line at the operating point.



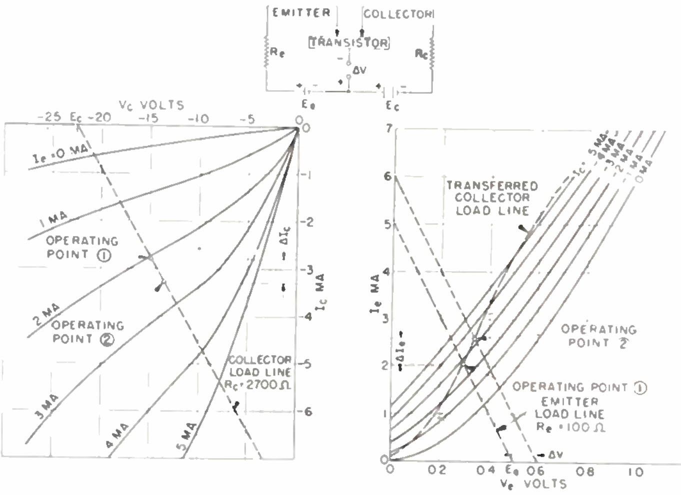
(a) (b)

Fig. 1—Transistor of typical characteristics connected as a voltage amplifier. (a) Collector (output) characteristic. (b) Emitter (input) characteristic.

If the input signal ΔV_e is traced through the input diagram to give ΔI_e, and this value is transferred to the output diagram, it can be seen to result in a voltage swing ΔV_c along the load line in the collector characteristic. For the example shown, the voltage gain $\Delta V_c/\Delta V_e$ is seen to be about 30. This is typical for an average transistor. The distortion of this amplifier depends on the curvature of the transferred load line at the operating point. At the operating point chosen for the example there is considerable curvature and therefore distortion. To illustrate this, an operating point at 0.5 volt and 4 milliamps in the emitter plane would show practically no distortion, since the transferred load line has an inflection point in this neighborhood and is nearly linear over quite a range. The characteristics of nearly all transistors show an inflection point in the transferred load line so that there is some region of reasonable extent which may be picked for distortionless operation.

In the example shown, the input impedance is quite low (about 100 ohms) while the output impedance is moderate (2,700 ohms). Since ΔI_e nearly equals ΔI_c, this impedance ratio is seen to be primarily responsible for the voltage amplification. This means that one could not design a multistage voltage amplifier using transistors of such characteristics in direct cascade without some sort of transformer coupling which would bring the output impedance of one stage more nearly in line with the input impedance of the following stage. It is possible, however, to use a transistor of these characteristics as a current amplifier in such a way that a multistage amplifier may be designed having alternate stages of voltage and current amplification without having to resort to transformer coupling.

In order to use the transistor as a current amplifier of considerable gain, one must utilize feedback in one form or another. One direct method of doing this is to use the base lead of the transistor for the input, and the emitter resistance R_e as the output. Such a situation is shown in Fig. 2. As before, the first step in analyzing this circuit is to draw the load line R_c in the collector characteristic plane and transfer this load line point by point to the emitter characteristic plane. The quiescent operating point (operating point 1) is determined by the intersection of this transferred load line and the emitter load line R_e in the emitter plane. A signal voltage ΔV applied at the input terminals, and of such a polarity as to increase the emitter current, will effectively add to the emitter bias voltage E_e, and subtract from the collector supply voltage E_c. Since $|E_c| \gg |E_e|$ we will neglect the displacement of R_c and consider only the displacement of R_e, as shown in the emitter characteristic. This new load line determines a new operating point (operating point 2). If these two operating points are transferred back to the collector plane, a value of ΔI_c may be read.



(a) (b)

Fig. 2—Transistor of typical characteristics connected as a base-input amplifier. (a) Collector characteristic. (b) Emitter characteristic.

Since the current in the base lead is the algebraic sum of ΔI_c and ΔI_e, and ΔI_c is in general negative when ΔI_e is positive, it is easy to see that the input impedance may be either positive or negative, depending upon the sign of this algebraic sum. If the resistances R_e and R_c are so chosen that $|\Delta I_e| > |\Delta I_c|$ for the polarity of test voltage shown in the example, the input impedance is positive, and the current gain ξ is given by $\Delta I_e/\Delta I_e+\Delta I_c$. (The current through the emitter load resistance R_e is considered the output current.) The condition that $|\Delta I_e| > |\Delta I_c|$, mentioned above, is easily satisfied for any transistor, regardless of the magnitude of its short circuit current gain by simply making R_e large enough.

By reference to Fig. 3 we will derive a graphical construction for the determination of R_c to provide a desired current gain ξ in such a current amplifier working at an arbitrary operating point. Fig. 3 (a) shows a portion of a collector plane in which a load line R_c makes the angle θ with the current axis, and the perpendicular to the lines of constant emitter current through the operating point makes the angle β with the current axis. δl represents the portion of the load line covered with a given signal ΔV across the base terminals. The projection of this segment on the current axis gives the collector-current change δI_c, and its projection on the perpendicular to the lines of constant I_e gives the change in emitter current δI_e. Let ΔL_c be the length in this plane of one unit of collector current and ΔL_e be the length in this plane of one unit of emitter current as shown.

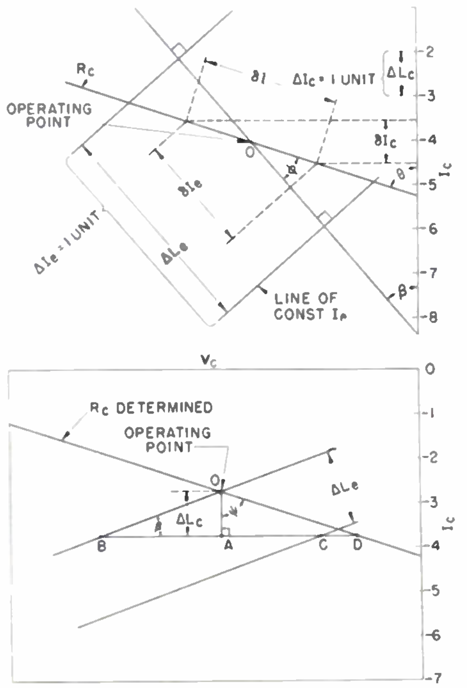


Fig. 3—Graphical construction for determining R_c in a current amplifier of arbitrary gain ξ for a given operating point. (a) Collector plane. (b) Collector plane construction.

From Fig. (3a) then:

$$\left.\begin{aligned} \delta I_e &= \frac{\delta l}{\Delta L_e}\cos\phi \\ \delta I_c &= \frac{-\delta l}{\Delta L_c}\cos\theta \end{aligned}\right\}; \tag{1}$$

and from the above definition of current gain ξ, we have

$$\xi(\delta I_e + \delta I_c) = \delta I_e; \tag{2}$$

substitution of (1) into (2) gives the relation

$$\xi\left(\frac{\delta l}{\Delta L_e}\cos\phi - \frac{\delta l}{\Delta L_c}\cos\theta\right) = \frac{\delta l}{\Delta L_e}\cos\phi. \tag{3}$$

From the geometry of the diagram, $\phi = \theta - \beta$, whence $\cos\phi = \cos(\theta-\beta) = \sin\theta\sin\beta + \cos\theta\cos\beta$. Substituting in (3) and multiplying by $\Delta L_e/\xi$ gives

$$\sin\theta\sin\beta + \cos\theta\cos\beta - (\Delta L_e/\Delta L_c)\cos\theta = (1/\xi)(\sin\theta\sin\beta + \cos\theta\cos\beta).$$

Dividing by $\cos\theta$ gives

$$(\tan\theta\sin\beta + \cos\beta)\left(1 - \frac{1}{\xi}\right) = \frac{\Delta L_e}{\Delta L_c},$$

or

$$\tan\theta = \frac{\Delta L_e}{\Delta L_c}\,\frac{\xi}{\xi - 1}\csc\beta - \cot\beta. \tag{4}$$

Thus $\tan\theta$, the slope of the desired load line, is given in terms of the required gain ξ and certain functions of the volt-ampere characteristics.

Equation (4) may be readily solved graphically by the procedure illustrated in Fig. 3(b). Draw a line OA of length ΔL_c parallel to the I_c axis through the operating point O. Draw BC through A parallel to the V_c axis. The angle OBA is now the angle β, and from the geometry of the diagram

$$\left.\begin{aligned} BA &= \Delta L_c\cot\beta \\ BC &= \Delta L_e\csc\beta \end{aligned}\right\}. \tag{5}$$

The line BC is extended to D making

$$BD = \frac{\xi}{\xi - 1}BC. \tag{6}$$

The desired load line R_c is now drawn through O and D. From geometry and (5) and (6),

$$\begin{aligned} \Delta L_c\tan\psi &= AD = BD - BA \\ &= \Delta L_e\frac{\xi}{\xi - 1}\csc\beta - \Delta L_c\cot\beta. \end{aligned}$$

Dividing by ΔL_c and comparing to (4), we see that,

$$\tan\psi = \frac{\Delta L_e}{\Delta L_c}\,\frac{\xi}{\xi - 1}\csc\beta - \cot\beta = \tan\theta, \tag{7}$$

proving that the desired load line R_c is indeed the line OD.

The input resistance R_i of such a current amplifier depends now on the resistance R_e in the emitter circuit. In order to determine R_e to give an arbitrary input impedance R_i, where

$$R_i = \frac{\Delta V}{\delta I_e + \delta I_c} = \frac{\xi\Delta V}{\delta I_e} \tag{8}$$

we will refer to Fig. 4. In Fig. 4(a) $\delta l'$ is the length of the segment of the transferred collector load line R_c which is swept out with the signal voltage ΔV. Its projection on the I_e axis is δI_e. The length $\Delta L_e'$ is equal to one unit of I_e in this plane and the length ΔL_v is equal to one unit of V_e. By inspection

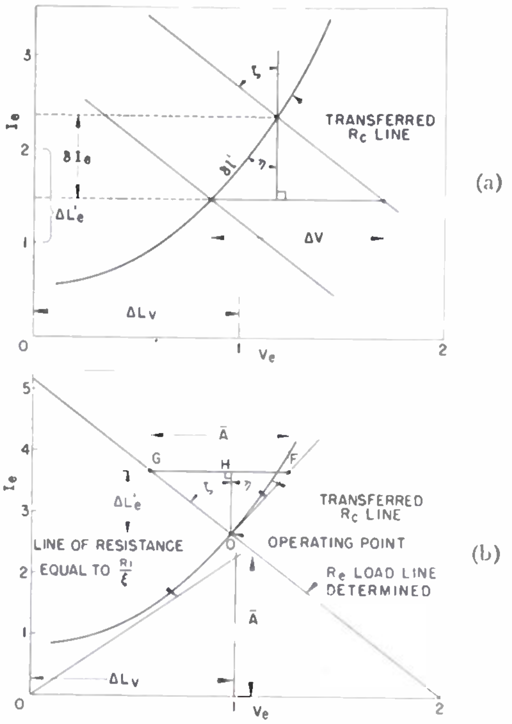


Fig. 4—Graphical construction for determining R_e in a current amplifier of arbitrary gain ξ and input impedance R_i for a given operating point. (a) Emitter plane. (b) Emitter plane construction.

$$\left.\begin{aligned} \delta I_e &= \frac{\delta l'}{\Delta L_e'} \cos\eta \\ \Delta V &= \frac{\delta l'}{\Delta L_v} \sin\eta + \left(\frac{\delta l'}{\Delta L} \cos\eta\right) \tan\zeta \end{aligned}\right\} \tag{9}$$

where η is the angle between $\delta l'$ and a parallel to the I_e axis and ζ is the angle the load line R_e makes with this axis. By substituting (9) into (8) we obtain the relations:

$$\begin{aligned} R_i &= \xi\left(\frac{\Delta L_e'}{\Delta L_v} \{\tan\eta + \tan\zeta\}\right) \\ \tan\zeta &= \frac{R_i}{\xi}\frac{\Delta L_v}{\Delta L_e'} - \tan\eta. \end{aligned} \tag{10}$$

In (10) the slope of the desired emitter load line ($\tan\zeta$) is given in terms of the desired current gain ξ, and the desired base input resistance R_i. The other quantities in the equation may be determined from the emitter volt-ampere characteristics.

With the aid of Fig. 4(b) we may readily solve (10) graphically. From the operating point O, an ordinate of length $\Delta L_e'$ is erected. Through its upper end H, a horizontal line is drawn which intersects, in the point F, the tangent to the transferred R_c line at the operating point. From the geometry we see that

$$HF = \Delta L_e' \tan\eta. \tag{11}$$

Now a line of resistance R_i/ξ is drawn through the origin and its ordinate $\bar{A}$ at $V_e = 1$ is determined. By geometry,

$$\bar{A} = \frac{R_i}{\xi}\Delta L_v. \tag{12}$$

The length $\bar{A}$, laid off along FH, determines the point G. Finally, we see by geometry that,

$$GH = \Delta L_e' \tan\zeta = \bar{A} - HF. \tag{13}$$

If (11) and (12) are substituted into (13) and the whole equation is divided by $\Delta L_e'$, we obtain (10), proving that the line GO determines the desired emitter load line R_e.

We have now completed the design of our current amplifier with a given gain and input impedance, using only graphical construction in the dc emitter and collector characteristic planes. In design work this procedure may take the place of the equivalent circuit analysis cited in the references, and seems to be a much simpler and faster method to use.

The base-input circuit of Fig. 2 has been described as a current amplifier. The same circuit can be used as a high-input-impedance voltage amplifier if the collector resistance R_c is used as the output resistance. If the input signal ΔV is traced through the emitter diagram to give ΔI_e, and this value is transferred to the collector diagram it is seen to result in a voltage swing along the collector load line of about 1.5 volts. In this example then the voltage gain would be about 15.

In discussing the voltage amplifier of Fig. 1, it was pointed out that a multistage amplifier could not be made using emitter input circuits in direct cascade without some means of impedance matching between the stages, such as transformers. From the above analysis of the base-input current amplifier, it is clear that in most cases it should be possible to design the input impedance of such an amplifier to match the output impedance of the emitter-input voltage amplifier so that a multistage amplifier could be built by using alternate stages of voltage and current amplification without having to insert impedance-matching components. The base-input circuit when used as a high-input-impedance voltage amplifier may be directly cascaded. In such a case the input resistance R_i (10) may be adjusted to equal the output resistance R_c by adjusting the emitter resistance R_e in each stage, as described above.

From (8) we see that the input impedance of a base-input circuit becomes infinite if the current gain ξ becomes infinite. This is equivalent to saying that $\delta I_e = \delta I_c$. Under these conditions the construction of Fig. 3(b) reduces to drawing the load line through OC, since $(\xi/\xi-1) \rightarrow 1$ as $\xi \rightarrow \infty$. The load resistance R_e, determined in this way is the lowest load resistance that can be used without making the input impedance R_i, negative. If lower values of R_e are used and an LC tank circuit is inserted across the input terminals in the base lead, the system will oscillate with the frequency determined by the tank circuit. The above graphical construction can then be used to determine both the critical values of R_e required for oscillation, and the region in the dc collector characteristic plane in which the transistor may be made to oscillate (the region in which the critical value of R_c is greater than 0).

The region of possible oscillation in the dc collector-characteristic plane is bounded by a contour on which the points A and C of the construction of Fig. 3(b) coincide. If we define a current gain $\alpha = (\partial I_c/\partial I_e)_{V_c}$ (according to the literature)[3] we see that for $\alpha = 1.0$ the above-mentioned coincidence occurs. The region of possible oscillation is then bounded by a contour of $\alpha = 1.0$. Such a contour may easily be plotted by inspection since $\alpha = (\partial I_c/\partial I_e)_{V_c} = 1.0$ means simply that the vertical separation of the constant-emitter-current lines should equal one unit on the collector current scale if the constant-emitter-current lines are drawn for the same units of emitter current.

In the more general case, we may bound the region of the collector characteristic plane in which ξ can be made equal to, or greater than, some desired value ξ_0. This means in the construction of Fig. 3(b) that the points A and D would coincide on this boundary when the length BC has been multiplied by $\xi_0/(\xi_0 - 1)$ to get the length BD. Such a condition is illustrated in Fig. 5. By similar

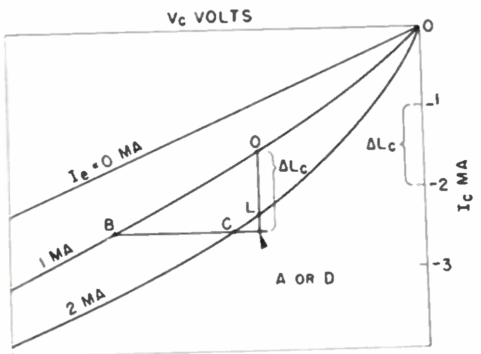


Fig. 5—Collector plane construction for the derivation of equation (17).

triangles, we see that

$$\frac{OL}{OD} = \frac{OL}{OA} = \frac{BC}{BD}. \tag{14}$$

By construction,

$$\frac{BC}{BD} = \frac{\xi_0 - 1}{\xi_0} \tag{15}$$

[3] See page 364 of footnote reference 1.

and by definition,

$$\alpha = \left(\frac{\partial I_c}{\partial I_e}\right)_{V_c} = \frac{OL}{\Delta L_c} = \frac{OL}{OA}. \tag{16}$$

Substituting (15) and (14) into (16), we get

$$\alpha = \frac{\xi_0 - 1}{\xi_0} \tag{17}$$

on the boundary of the region in which $\xi \gtreqless \xi_0$. This means, for instance, that if we want to design a current amplifier with a gain of 10, we must choose the operating point in the collector characteristic plane in a region where the $\alpha \gtreqless 0.9$.

In the region of oscillation discussed above, ξ is negative. All of the foregoing equations still hold for ξ negative, so that we may compute the negative input resistance R_i from (10) as easily as we may compute a positive input resistance. In designing a simple base-input trigger circuit, such as that discussed by Reich and Ungvary,[4] one may determine the lowest value of negative base input resistance obtainable with a given transistor by first picking the point of maximum α in the collector plane. This value of α determines in (17) the lowest possible value of $\xi = 1/(1-\alpha)$. Next, the V_e ordinate through this point is transferred to the emitter plane and the slope of this transferred line is read at the same point, to obtain $\tan\eta$. The desired input resistance is then computed from (10) in the form

$$R_i = \frac{1}{1-\alpha}\left\{\frac{\Delta L_e'}{\Delta L_v}\tan\eta\right\}. \tag{18}$$

(Tan ζ and tan θ are both set equal to zero in this computation to find the lowest value of R_i possible.) If it is desired to have some resistance in the collector circuit, the value of ξ would have to be computed from (4).

These few examples should suffice to illustrate the graphical analysis of transistor characteristics for the design of simple circuits. Such methods are not easily extended to complex circuits, but the analysis of some types of more complex circuits (such as multistage amplifiers) can be done by these methods in successive steps.

Acknowledgement

The author wishes to acknowledge his indebtedness to J. W. Coltman for suggesting the construction of Fig. 3(b), and for a helpful discussion of the work.

[4] H. J. Reich and R. L. Ungvary, "Transistor trigger circuit," *Rev. Sci. Instr.*, vol. 20, pp. 586–588; August, 1949.

Reactance Chart*

HAROLD A. WHEELER†, FELLOW, IRE

Summary—**The time-honored chart of reactance, frequency, inductance, and capacitance is extended in range, with added scales of susceptance, wavelength, and time constant. Simple geometric patterns are given which enable the chart to be used for the direct solution of various problems such as the bandwidth of a resonant circuit, some properties of a transmission line (wave impedance and delay), and half sections of the usual kinds of constant-k filters (low-pass, high-pass, band-pass).**

I. Introduction

Since 1928, the reactance chart has been one of the outstanding aids to radio engineers. It is here presented as Figs. 6 and 7 (see pages 1394 and 1395) with the following improvements:

1. A wavelength scale is added at the top of the chart giving a direct conversion between frequency and wavelengths.
2. A time-constant scale is added at the bottom, giving the time constant *CR* or *L/R*, or the time delay in a transmission line or filter.
3. A conductance or susceptance scale is added at the left side, the reciprocal of resistance or reactance.
4. The frequency scale of Fig. 7 covers from 0.1 cycle to 100,000 Mc (3 mm wavelength) in two ranges. The scales on the left side are common to both ranges. The other scales have upper and lower sets of units. All the upper units are used together for the low-frequency range, the lower units for the high-frequency range.

The following instructions describe the use of the chart in many problems, including the complete design of constant-k filters.

II. General Instructions

A point on the chart is the intersection of four lines, one each for frequency f, reactance X, inductance L, and capacitance C. Any two of these quantities determines the point and thereby the other two quantities.

Fig. 6 is a single square of the chart, enlarged for accuracy of reading. If accuracy is desired, the problem is first computed on Fig. 6, all except the decimal point. Then Fig. 7 is employed to locate the decimal point and to give a rough check on the number.

In locating a number on the inductance or capacitance scales of Fig. 6, it is important that the decimal point be shifted by an even number of places.

If accuracy is not required, only Fig. 7 is used. This is good for one or two significant figures and the decimal point is located in the numbers and units on the scales.

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† Wheeler Laboratories, Great Neck, L. I., N. Y.

III. Abbreviations

c = cycle per second
s = second
m = meter
Ω = ohm
℧ = mho
h = henry
f = farad
M = mega (10^6)
μ = micro(10^{-6}).

IV. Reactance and Resonance

Disregarding the sign of the reactance, the basic formulas for this chart are as follows:

$$X = \omega L = 2\pi f L \quad \text{ohms (1)}$$

$$X = \frac{1}{\omega C} = \frac{1}{2\pi f C} \quad \text{ohms (2)}$$

in which

X = reactance of L or C (ohms)
f = frequency (cycles per second)
$\omega = 2\pi f$ = radian frequency
L = inductance (henries)
C = capacitance (farads).

If L and C form a resonant circuit as in Fig. 1, these two formulas merge into the resonance formulas

$$X_0 = \omega_0 L = \frac{1}{\omega_0 C} = \sqrt{\frac{L}{C}} \quad \text{ohms (3)}$$

$$\omega_0 = \frac{1}{\sqrt{LC}} \quad \text{radians per second. (4)}$$

In which the subscript "0" denotes resonance.

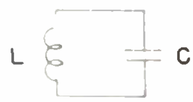


Fig. 1—Resonant circuit.

Fig. 2 shows the pattern representing the above four formulas for reactance and resonance.

The susceptance corresponding to reactance X is $B = 1/X$. This is given on the reciprocal scale on the left side.

The wavelength corresponding to frequency f is

$$\lambda = \frac{c}{f} = \frac{2\pi c}{\omega} \quad \text{meters (5)}$$

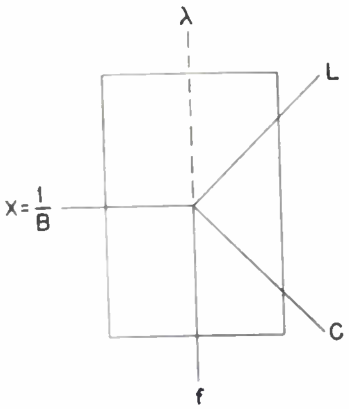


Fig. 2—Solution of reactance and resonance.

in which

$c = 3\times10^8$ meters per second
$= 300$ meters per microsecond
$=$ speed of light.

V. Resistance and One Kind of Reactance

A combination CR or L/R behaves as a low-pass or high-pass filter. Fig. 3 shows the typical combinations of this kind. Each presents a voltage attenuation ratio of $1/\sqrt{2}$ (3 db) at a nominal cutoff frequency f_c such that

$$R = \omega_c L \quad \text{or} \quad \frac{1}{\omega_c C} \qquad \text{ohms. (6)}$$

Fig. 4 shows the solution of this problem on the chart.

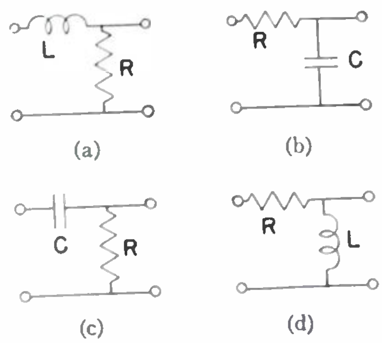


Fig. 3—Resistance and one kind of reactance: (a) and (b) low-pass; (c) and (d) high-pass.

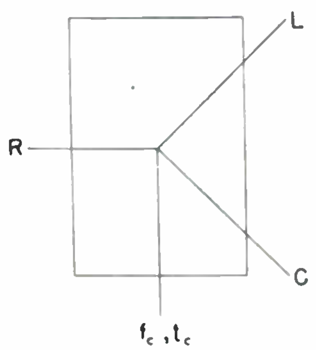


Fig. 4—Solution of low-pass and high-pass filters.

Each of the networks of Fig. 3 has a charging or discharging time constant

$$t_c = \frac{1}{\omega_c} = \frac{L}{R} \quad \text{or} \quad CR \qquad \text{seconds. (7)}$$

An extra scale below the chart gives this time constant. It is noted that the subdivisions of this scale are provided by diagonal lines meeting to form a "V" at the bottom edge of the chart where each subdivision should be. The time constant is the radian period corresponding to the frequency.

VI. Resistance and Resonance

A sharply resonant circuit with resistance as shown in Fig. 5(a) behaves as a band-pass filter. Relative to the peak, it presents a voltage attenuation ratio of

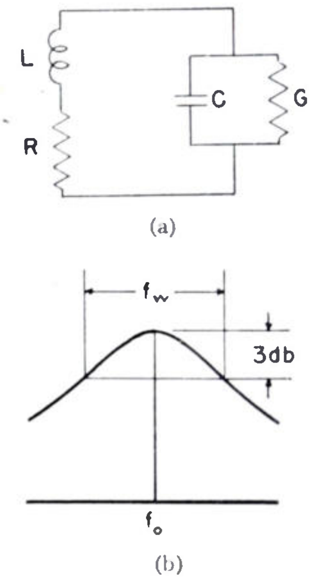


Fig. 5—Resistance in a resonant circuit.

$1/\sqrt{2}$ (3 db) at a nominal bandwidth f_w indicated in Fig. 5(b). The series R and shunt G contribute parts of the bandwidth as follows:

$$f_w = f_u + f_v \ll f_0 \qquad (8)$$

$$\omega_u = \frac{1}{t_u} = \frac{R}{L}; \qquad \omega_v = \frac{1}{t_v} = \frac{G}{C} \qquad (9)$$

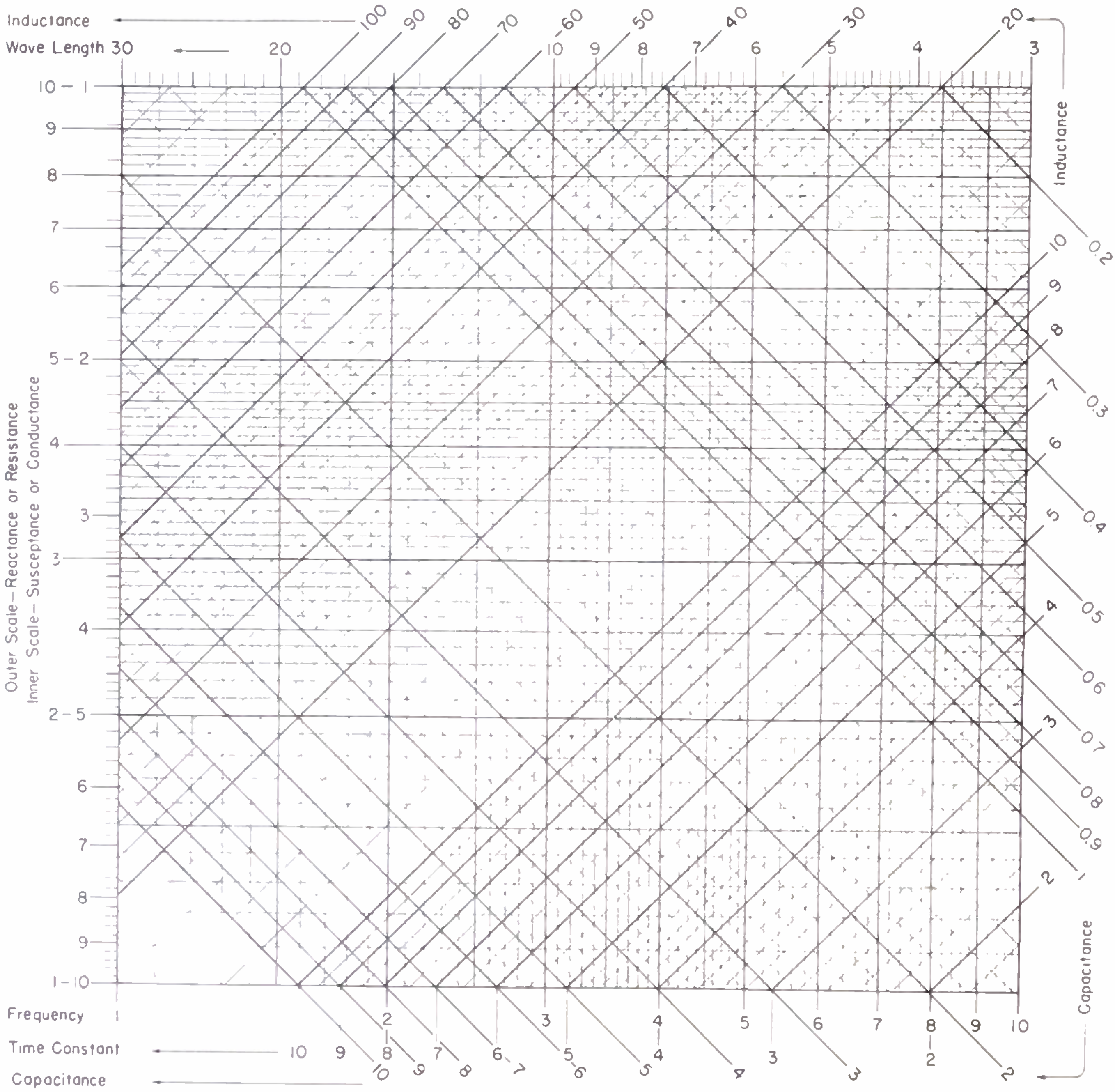
$$\omega_w = \frac{1}{t_w} = \frac{R}{L} + \frac{G}{C} \qquad (10)$$

in which

$t_u =$ time constant of L/R
$t_v =$ time constant of C/G
$t_w =$ half time constant of damping of free oscillations in the resonant circuit.

Fig. 8 shows the pattern of all these relations and others on the chart, involving five points of intersection. Since the bandwidth does not involve the frequency of

Note. On the scales of inductance and capacitance, both decimal points must be shifted by even numbers of places, or both by odd numbers of places, to interchange the scales on this chart with the actual values in henries (Mh, h, μh, μμh) and farads (f, μf, μμf, μμμf). This rule must be followed if both inductance and capacitance appear in the same computation.



$$X \text{ or } R = 2\pi f L = \frac{1}{2\pi f C} = \sqrt{\frac{L}{C}} = \frac{L}{t_c} = \frac{t_c}{C}$$

$$f = \frac{1}{2\pi\sqrt{LC}} = \frac{X}{2\pi L} = \frac{1}{2\pi C X} = \frac{1}{2\pi t_c} = \frac{300}{\lambda} \times 10^6$$

$$L = \frac{X}{2\pi f} = \frac{1}{4\pi^2 f^2 C} = CR^2 = R t_c = \frac{t_c^2}{C}$$

$$t_c = \sqrt{LC} = \frac{L}{R} = CR = \frac{1}{2\pi f} = \frac{\lambda}{2\pi \times 300} \times 10^{-6}$$

$$C = \frac{1}{2\pi f X} = \frac{1}{4\pi^2 f^2 L} = \frac{L}{R^2} = \frac{t_c}{R} = \frac{t_c^2}{L}$$

$$\lambda = 2\pi\sqrt{LC} \times 300 \times 10^6 = \frac{300}{f} \times 10^6 = 2\pi t_c \times 300 \times 10^6$$

Fig. 6—Enlargement of one square.

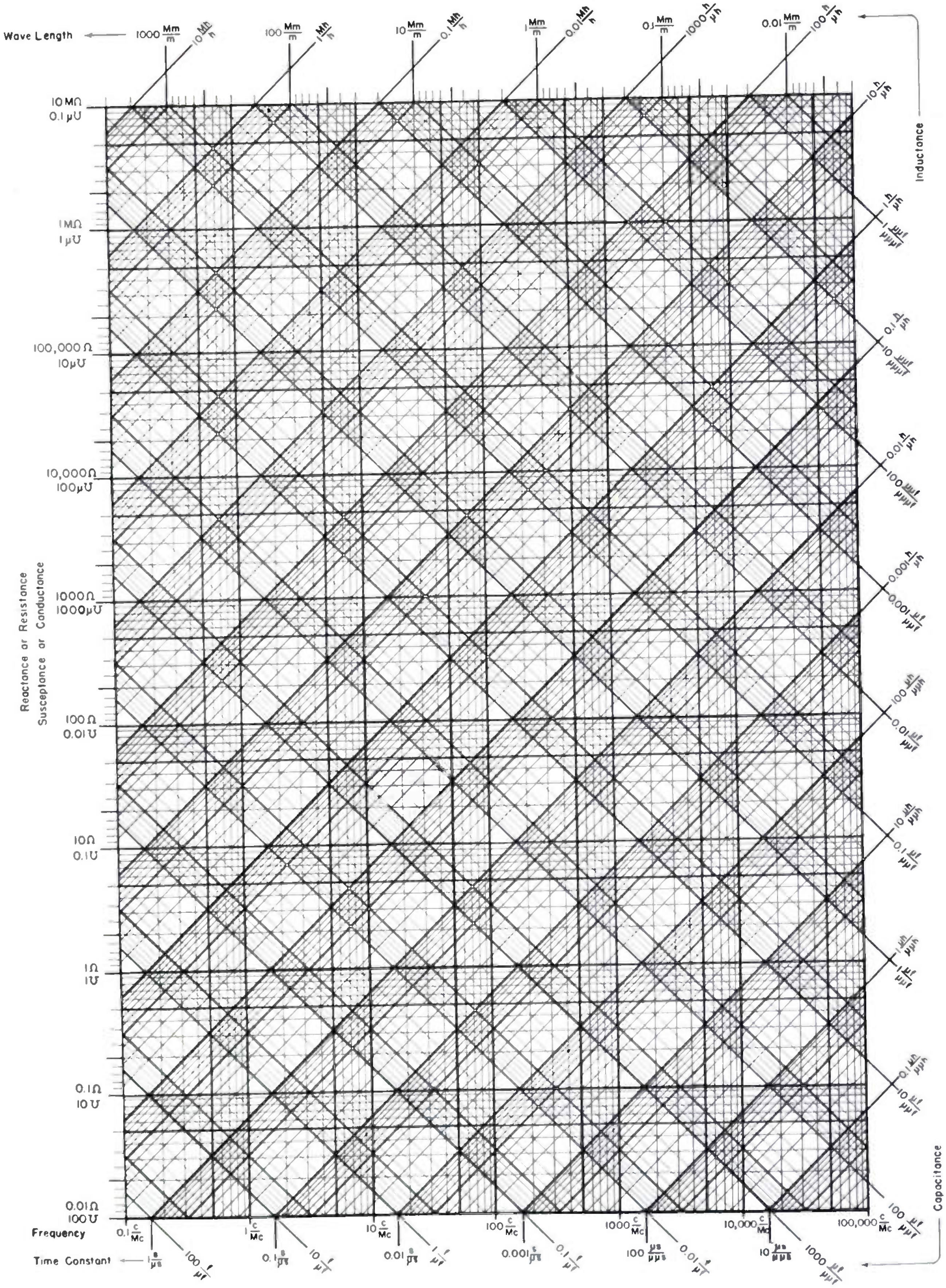


Fig. 7—Reactance chart.

resonance, the bandwidth may be determined separately.

The intersection of R and L determines f_u while that of G and C determines f_v. The sum of these is the nominal bandwidth f_w, which also determines the half time constant of damping, t_w on the time-constant scale.

The total effect of R and G may be regarded as concentrated in an equivalent series resistance R' or shunt resistance R'', such that

$$R' = \omega_w L \quad \text{or} \quad R'' = \frac{1}{\omega_w C}. \tag{11}$$

These formulas are closely associated with the ratio of reactance to resistance

$$Q = \frac{f_0}{f_w} = \frac{X_0}{R'} = \frac{R''}{X_0} \gg 1. \tag{12}$$

The equivalent series or shunt resistance, R' or R'', is determined by the intersection of f_w with L or C, respectively. This pattern of Fig. 8 gives a simple conversion between equivalent series and shunt resistance if either is given, together with L and C.

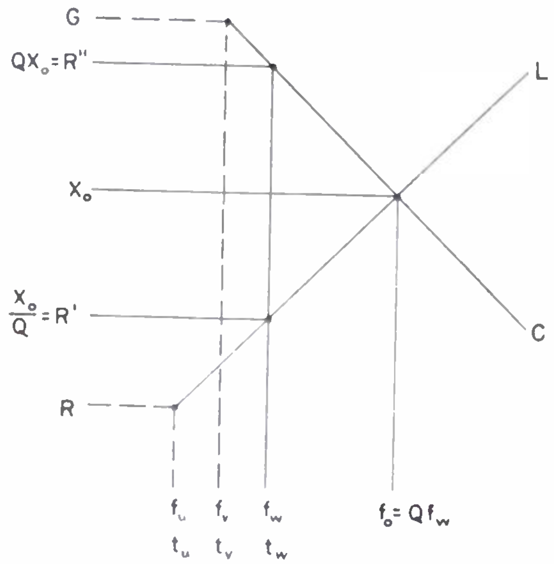


Fig. 8—Bandwidth of a resonant circuit.

The remaining point in Fig. 8 is the resonance point like Fig. 2. If either the series R or the shunt G is absent, this pattern simplifies by the disappearance of the dotted lines, because either f_u or f_v disappears and the other merges into f_w.

It may happen that the pattern of Fig. 8 for a given problem is divided between the two frequency ranges on the chart. This is true of circuits resonant in the neighborhood of 1 Mc. If many problems are to be encountered in such a region, a third scale may be added in red ink (or may be imagined) which is the mean of the two ranges marked on Fig. 7.

VII. Low-Pass and High-Pass Filters

Low-pass and high-pass filters of the constant-k type are shown in Fig. 9. The half section is the logical (but not usual) basis for filter design formulas, and is used in this treatment.

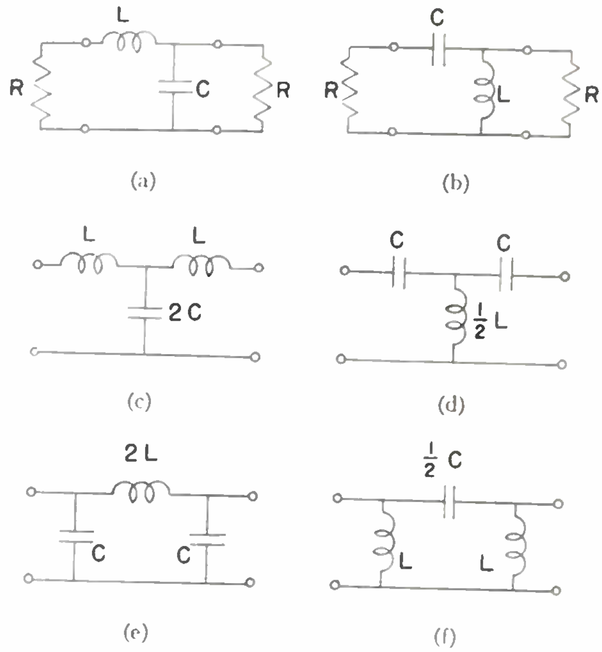


Fig. 9—Low-pass and high-pass filters to be solved by Fig. 4: (a) and (b) half sections; (c) and (d) mid-series sections; (e) and (f) mid-shunt sections.

On this basis, the low-pass and high-pass formulas are the same as (6) above, R being the nominal or "mid-band" image impedance. Therefore, these filters are designed directly by the pattern of Fig. 4.

In a low-pass filter, the time constant t_c is the delay per half section, based on the "mid-band" phase slope at frequencies much less than the cutoff frequency.

Either of these half-section filters with R on both sides is simply a critically damped resonant circuit whose frequency of resonance is f_c. Critical damping can be obtained by resistance on only one side of the half section if the value is changed to $2R$ in series or $R/2$ in shunt.

VIII. Band-Pass Filters

Band-pass filters of the constant-k type are shown in Fig. 10. If the cutoff frequencies are f_1 and f_2, the design formulas may be expressed as follows

$$\omega_2 - \omega_1 = \frac{R}{L_1} = \frac{1}{RC_2} \tag{13}$$

$$\omega_1\omega_2 = \frac{1}{C_1L_1} = \frac{1}{C_2L_2}. \tag{14}$$

These two expressions have in common L_1 and C_2. In (13) they are involved with R and the bandwidth f_2-f_1, and in (14) with C_1, L_2, and the mean frequency $\sqrt{f_1f_2}$.

These relations are respectively analogous to (11) and (4) above, from which follows the pattern of Fig. 11. The three points of intersection are determined by R, f_2, and f_1 in the usual practical problem, but the design is determined by any set of quantities sufficient to locate the three points. The pattern is shown for cases in which the bandwidth is less or greater than the mean frequency.

A band-rejection filter is computed by the same procedure, by merely interchanging the series and parallel arms in the half section of Fig. 10(a).

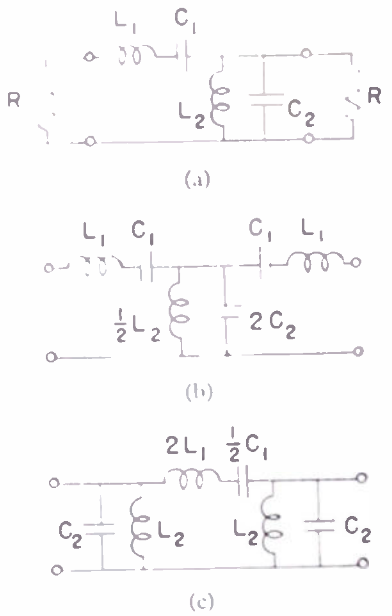


Fig. 10—Band pass filters. (a) Half section. (b) Mid series section. (c) Mid shunt section.

IX. Transmission Lines

The transmission line of Fig. 12 has two characteristics of interest here, its wave impedance and its time of delay.

The wave impedance is

$$R = \sqrt{\frac{L}{C}} \tag{15}$$

in which L and C are uniformly distributed inductance and capacitance of any length of the line. This equation is solved by the pattern of Fig. 4.

The time of delay is

$$t_e = \sqrt{LC} \tag{16}$$

in which L and C are the total values for a certain length of line. This formula also is solved in Fig. 4.

Both of these formulas apply also to any number of sections of low-pass filter, L and C being the total series inductance and shunt capacitance.

Acknowledgment

The writer expresses his special appreciation of the skill and ingenuity of E. A. Owen in preparing the charts.

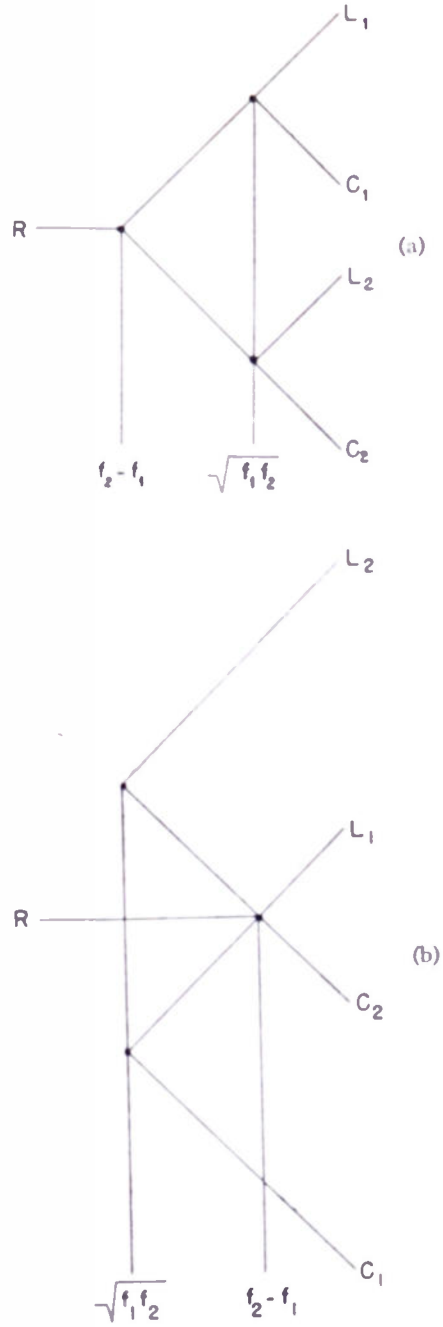


Fig. 11—Solution of band-pass filters.

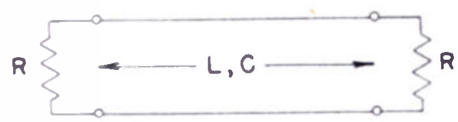


Fig. 12—Transmission line, to be solved by Fig. 4.

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Inductance Chart for Solenoid Coil*

HAROLD A. WHEELER†, FELLOW, IRE

Summary—**A simple chart presents the relation between inductance, over-all dimensions, and density of winding for a solenoid coil. Any one unknown may be determined if the other quantities are given.**

I. Solenoid Coil

The chart to be described presents the relations among the dimensions and inductance of a solenoid coil. It presents them in such a form that any sufficient group of values may be given and the remaining values may be explicitly read from the chart. The chart is plotted on logarithmic scales covering a number of decades sufficient for nearly all applications of solenoid coils. The decimal point is placed so there is no ambiguity. The scale of winding density is self-computing for close windings of various wire gauges and types of insulation.

Fig. 2 (opposite page) is this chart, including a small diagram which shows the pattern of intersecting lines used for each computation. Fig. 1 shows a cross section of a solenoid coil with all dimensions noted, as follows:

Dimensions in Inches

a = mean radius of coil
$2a$ = mean diameter of coil
b = axial length of coil
c = depth of multilayer coil
d = diameter of wire
$e = 1/m = b/n$ = pitch of winding
$m = 1/e = n/b$ = density of winding
$n = b/e = mb$ = number of turns.

The chart is based on the usual current-sheet formula which is accurate for many turns of fine wire, close-wound in a single layer. It is also accurate at low frequencies for one turn or many turns of thin ribbon, close-wound in a single layer. The wire is made of nonmagnetic material.

The following corrections are needed for special cases. The low-frequency cases apply if the current density in the wire is uniform. The high-frequency cases apply if the current flows in the surface of the wire, according to the skin effect.

II. Coil of One Turn

$$n = 1, \qquad m = 1/b, \qquad b < a.$$

This case may be computed, with an error less than 1/20 the value of inductance, by assigning the proper value to the axial length b; it is otherwise undetermined for one turn. Note that the two points of intersection on the chart are separated by one cycle on the horizontal scale.

At low frequencies, for solid wire:

$$b = c = \left(\frac{1}{2} \exp \frac{5}{4}\right) d = 1.74\, d; \quad d = 0.574\, b. \quad (1)$$

At low frequencies, for tubular wire of mean diameter $= d$; at high frequencies, for solid or tubular wire of outside diameter $= d$:

$$b = c = \left(\frac{1}{2} \exp \frac{3}{2}\right) d = 2.24\, d; \quad d = 0.446\, b. \quad (2)$$

At high frequencies, for ribbon of width $= d$:

$$b = c = \left(\frac{1}{4} \exp \frac{3}{2}\right) d = 1.12\, d; \quad d = 0.893\, b. \quad (3)$$

III. Coil of Few Turns

The accuracy of L is greatest if the ratio of pitch over wire diameter e/d has the value given in the preceding rules

IV. Multilayer Coil of Many Turns

For b, substitute $b+c$:

$$m = \frac{n}{b+c}; \qquad n = m(b+c). \quad (4)$$

The accuracy of L is within 1/20 if $c < a/2$.

Acknowledgment

The writer expresses his special appreciation of the skill and ingenuity of E. A. Owen in preparing this chart.

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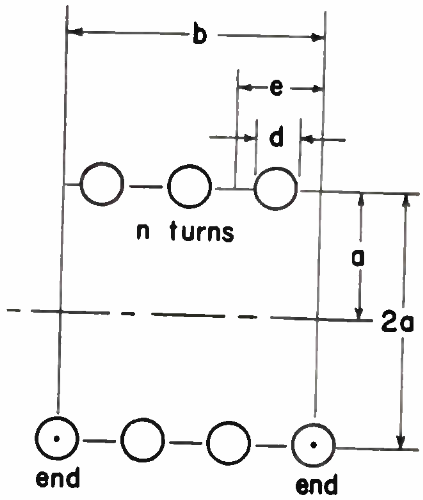

Fig. 1—Dimensions of solenoid coil.

* Decimal classification: R217.11×R382×R084. Original manuscript received by the Institute, February 13, 1950.
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† Wheeler Laboratories, Great Neck, L. I., N. Y.

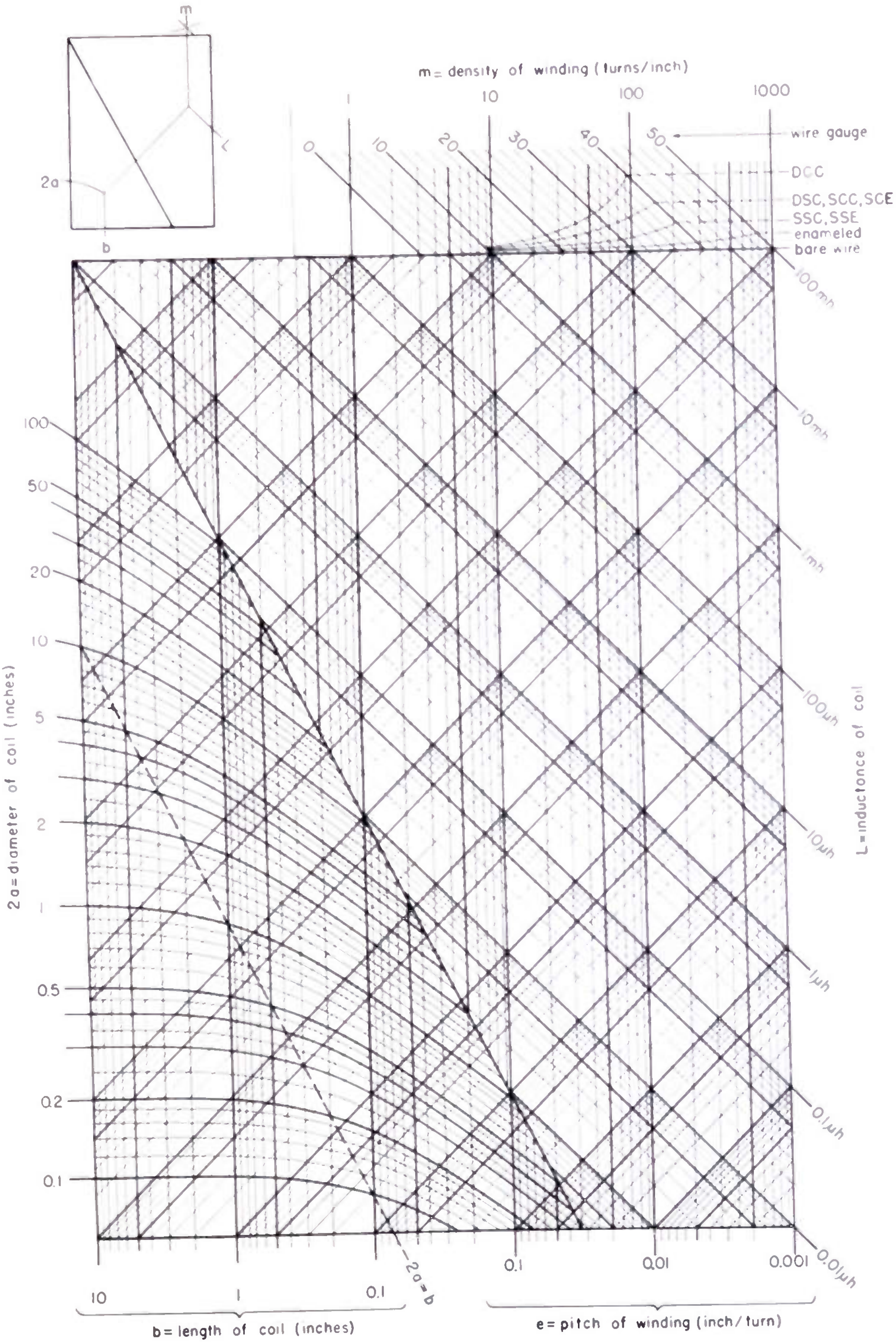

Fig. 2—Inductance chart.

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Transmission-Line Impedance Curves*

HAROLD A. WHEELER†, FELLOW, IRE

Summary—**A universal family of curves gives on one plot the wave resistance, inductance, and capacitance of transmission lines of one or two or four wires. Each curve represents one field pattern. An expanded scale includes the region of very low impedance, usually neglected. The seven field patterns plotted include inner conductors of circular cross section, in or near shields such as a nearby plane, a corner, parallel planes, a trough, and a coaxial square or circle.**

I. Introduction

In a transmission line, the same field patterns are involved in the wave resistance (R) and the inductance and capacitance per unit of length (L, C). Also, every field pattern of a two-wire line (balanced pair) may be bisected by a plane so as to occur about a one-wire line. Hence, one curve can present all these properties of one or two wires. A family of such curves is given to present the properties of one or two or four wires in various shields formed of one or more planes or of circular cross sections. On semilogarithmic co-ordinates, all the curves approach parallel straight lines for high-impedance transmission lines.

II. The Family of Curves

Figs. 1 and 2 (see pages 1402 and 1403) present a family of seven curves plotted on two different scales. Fig. 1 is plotted on the usual semilogarithmic co-ordinates, so that a coaxial line of circular inner and outer cross sections is plotted as a straight line. Fig. 2 is plotted on a special scale which expands the region of low impedance and causes each curve to have a certain finite value of its slope at the origin.

Each curve corresponds to a shield cross section which has all of its surfaces tangent to a circular cross section. The diameter D thereof is denoted the "maximum wire diameter," because it is the wire diameter that would touch the shield. The inner conductor is a wire having a circular cross section of a lesser diameter d.

Table I is a list of the seven field patterns, (a) to (g), with their description for one, two, or four wires. On Fig. 1, they are diagrammed for one or two wires, in the same order as the curves from top to bottom.

Fig. 1 and Table I have a column of the factors s which are a measure of how much space outside the "maximum wire diameter" is still inside the shield. A high-impedance line in any of the various shields has the same impedance as if the shield had a circular cross section of a diameter sD exceeding the "maximum wire diameter" by this factor. Beside each factor s is the number of ohms (in parentheses) by which this factor increases the wave resistance of one wire.

The curves are based on a perfect conductor, so the current travels on the outer surface of the inner diameter d and on the inner surface of the outer diameter D. For imperfect conductors, the capacitance is the same, but corrections will be given for the inductance and wave resistance.

Also, the curves are based on free space, which is the same as air for the precision of this treatment. If the line is filled with an insulating material having a dielectric constant k, the capacitance is multiplied by k and the wave resistance is divided by $\sqrt{k}$.

III. The General Formulas

If the diameter ratio D/d is so large that the field pattern is substantially circular near the wire, the properties of the line are given by the following simple logarithmic formulas:

$$R = R_0 \frac{n}{m} \frac{\log sD/d}{2\pi}$$

$$L = \mu_0 \frac{n}{m} \frac{\log sD/d}{2\pi}$$

$$C = \epsilon_0 \frac{m}{n} \frac{2\pi}{\log sD/d}$$

in which

R = characteristic resistance (ohms)
L = inductance per unit length (μh per meter)
C = capacitance per unit length ($\mu\mu f$ per meter)
$R_0/2\pi = 60$ ohms
$\mu_0/2\pi = 0.2$ μh per meter

* Decimal classification: R244.2×R084. Original manuscript received by the Institute, February 13, 1950.
This paper was prepared while the writer was associated with Hazeltine Service Corp., Little Neck, L. I., N. Y. It was first printed in July, 1942, in Hazeltine Report 1336W.
† Wheeler Laboratories, Great Neck, L. I., N. Y.

$\epsilon_0(2\pi) = 1{,}000/18 = 55.5\ \mu\mu f$ per meter
n = number of wires in series
m = number of wires in parallel
s = shield factor (defined above)
D/d = diameter ratio (defined above)
log = natural logarithm = 2.303 $\log_{10}$.

If the diameter ratio is only slightly greater than unity, exact formulas are known for only two of the cases, (a) and (g). This region is left blank in Fig. 1, but in Fig. 2 is enlarged and plotted. The latter is based on interpolation formulas derived by the writer, which are asymptotic for diameter ratios near unity and near infinity; they are close approximations for all ratios.

IV. The Current Distribution in the Conductors

The following corrections for current distribution are valid if the diameter ratio is substantially greater than unity in the straight regions of the curves in Fig. 1.

If the depth of penetration δ, as determined by the skin effect, is less than one-quarter the thickness of a nonmagnetic conductor, the inductance and, hence, the wave resistance are subject to a simple correction. In computing the inductance, use the values

d = (outside diameter of inner conductor) $-\delta$
D = (inside diameter of outer conductor) $+\delta$.

No such correction is needed for the capacitance. Therefore the wave resistance can be computed by applying $\delta/2$, instead of δ, as a correction to each diameter.

If the depth of penetration is much greater than one-quarter the thickness of a nonmagnetic conductor, the current distribution is substantially uniform. For a thin-walled tubular conductor, use the mean diameters in computing the inductance

d = (outside diameter of inner conductor) − (thickness)
D = (inside diameter of outer conductor) + (thickness).

In computing the wave resistance, use one-half of each correction.

In the case of a nonmagnetic solid wire with uniform current distribution, the effective diameter for computing the inductance is

$d = 0.779$ (wire diameter)

and for computing the wave resistance.

$d = 0.882$ (wire diameter).

The amount of increase of inductance from this cause is indicated by a marker (*) on the scale. That of the wave resistance is one-half as high on the graphs, and is indicated by an extra horizontal line crossing the R scale near the bottom. These corrections are especially important if a line is to be tested at low frequencies and used at high frequencies

V. Bifilar Conductors

Case (a) for two wires is an example how equal currents in opposite directions cause the same field pattern as if a shield plane were interposed between the two conductors. Likewise, case (c) for one or two wires gives the effect of a grid of parallel wires with currents alternately in one direction and in the opposite direction.

The so-called Ayrton-Perry noninductive resistor is an example of such a grid of wires. Two wires connected in parallel ($n=1$, $m=2$) are wound "noninductively" in a single layer. Their inductance is one-half that of one wire on the graphs for case (c) with the added correction (*).

Acknowledgment

The author expresses his special appreciation of the skill and ingenuity of E. A. Owen in preparing these curves.

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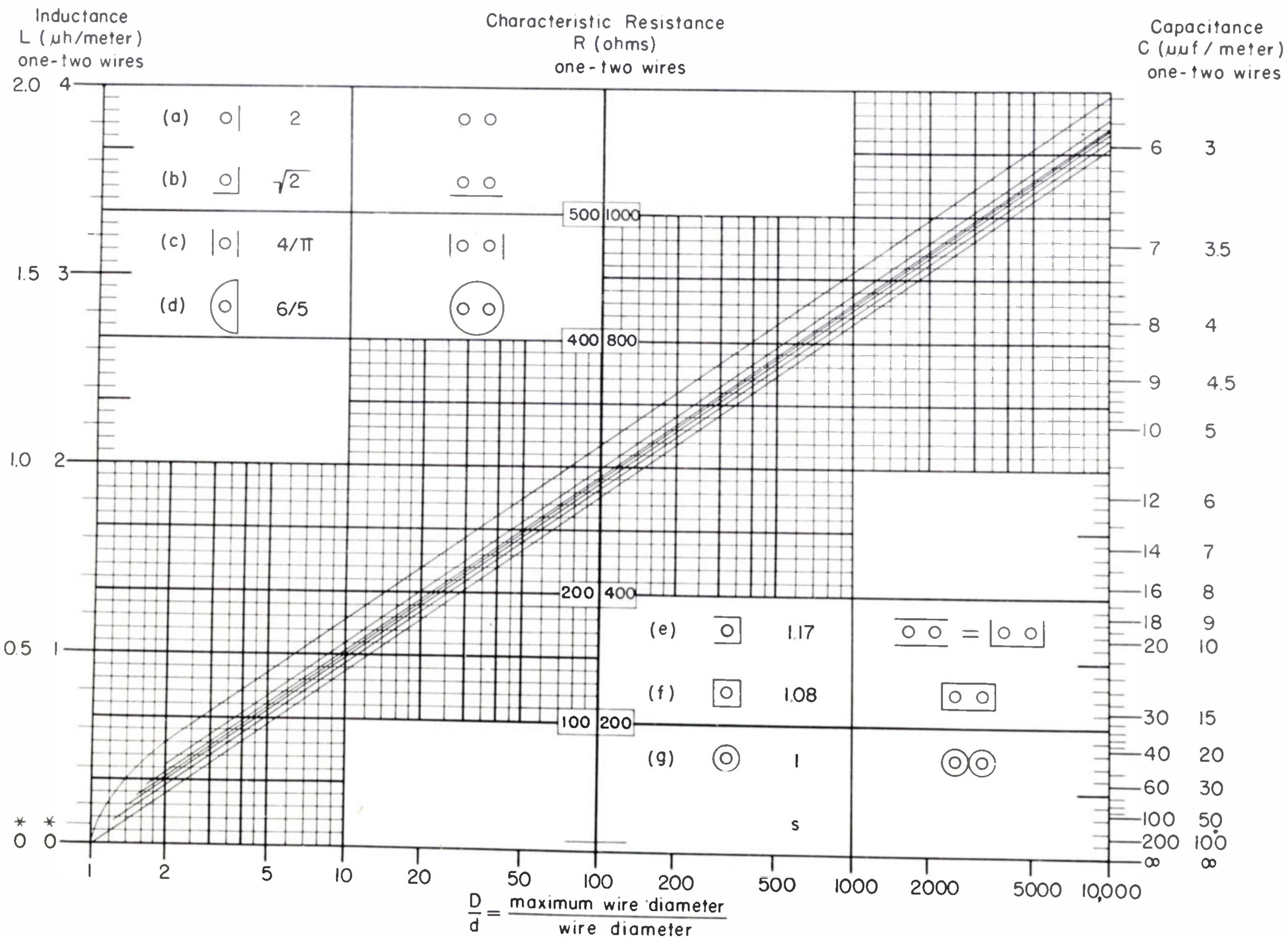
TABLE I
List of Field Patterns

Factor s	(Ohms)	One Wire	Two Wires (Balanced Pair)	Four Wires (Balanced Quad)
(a) 2	(41.5)	Near a plane	In open space	—
(b) $1.414=\sqrt{2}$	(20.8)	In a corner	Near a plane	In open space
(c) $1.273=4/\pi$	(14.5)	Between two planes	Between two planes	—
(d) $1.2\ \ =6/5$	(10.9)	In a semicircular tube	In a circular tube	—
(e) $1.170=(4/\pi)\tanh(\pi/2)$	(9.4)	In a channel	In a channel	Between two planes
(f) 1.079	(4.5)	In a square tube	In a rectangular tube	In a square tube
(g) 1	(0)	In a circular tube	In two circular tubes	In four circular tubes

Note—Since the four wires are connected in series-parallel, they take the same scales as one wire on the graphs.

The curves are in the same vertical order as the diagrams.

If dielectric constant k >1, multiply C by k, divide R by $\sqrt{k}$.



Maximum wire diameter is that which touches all other surfaces at once.

Fig. 1—Curves of wave resistance, inductance, and capacitance.

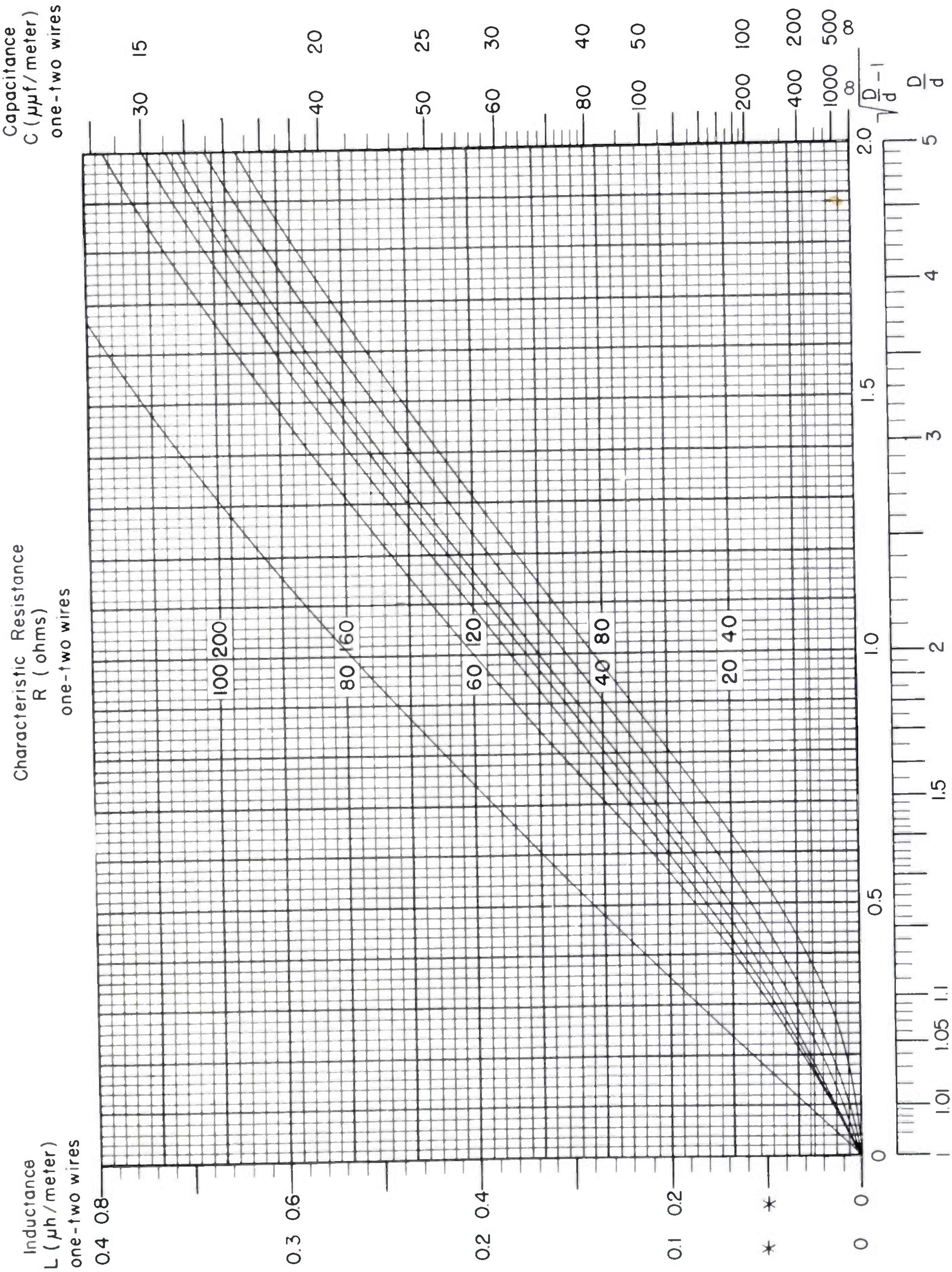


Fig. 2—Curves for lines of low impedance.

The Simplification of Television Receivers*

W. B. WHALLEY†, ASSOCIATE, IRE

Summary—**The minimum number of functions required in a TV receiver is analyzed with the purpose of reducing the required components and tubes while maintaining high quality of performance and all normally desirable features such as AGC and horizontal AFC. One of the approaches to this end has been a study of the feasibility of combining different functions in a common tube. A receiver incorporating some of the results of this study is described. Measured data taken on this receiver are presented and its general features are discussed.**

THIS PAPER, as the title indicates, describes an investigation into the general means of simplifying television receivers so as to reduce the costs of production and servicing. An account is given of several approaches to the problem which were found valuable in attaining the objectives.

Reasons for Simplification

There are many reasons for considering the possibilities of simplifying television receivers. Some are, of course, obvious since a reduction in the number of components has a cumulative effect in reducing the number of leads and connections, permits the use of a smaller chassis and cabinet, and requires less power and consequently smaller power transformers, filter capacitors, and choke.

In addition, however, there can be an improvement in reliability and ease of servicing as the number of components and related connections is reduced. This paper may, therefore, be regarded as describing an inevitable trend in the industry.

General Procedure

The first step in this program was to analyze the operation of a television receiver from the standpoint of the minimum number of necessary functions, and then to plan the simplest possible circuit to perform each function, at the same time keeping in mind the possibility of combining two functions in the same circuit.

In parallel with the analysis, a survey of the circuits of contemporary television receivers was made and trends in simplification noted.

It should be emphasized that the study program and the experimental work were predicated on designs having full bandwidth (4 Mc), good sensitivity, magnetic-type deflection circuits with horizontal automatic-frequency control, automatic gain control with moderate speed of response controlled from the video back-level voltage, good brightness such as that given by a $12\frac{1}{2}$-inch picture tube operating at 10,000 volts, low hum level, and good sound quality.

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† Sylvania Electric Products Inc., Bayside, L. I., N. Y.

It was also realized that, while considering the design changes in one section of the receiver, it was of major importance to relate such changes to the combination of circuits making up the whole receiver.

Experiments were then performed to test the new simplified circuits for the individual and combined functions, followed by the construction of a sample receiver incorporating several of the ideas evolved.

It may be advisable at this point to review briefly the functions of a television receiver in order that the discussion to follow may have better coherence. The various functions will be noted in a sequence which follows, as closely as possible, the path of the signal through the the receiver. Some general remarks as to the simplification and combination will be included.

1. Channel Selection and Radio-Frequency Amplification

Much work has been in progress on tuners, and there are available two or three types having reasonably good image rejection and noise figure, yet requiring only two tubes. It is probable that the circuit suggested by Wallman, Macnee, and Gadsden[1] would give a better signal-to-noise ratio than presently available tuners and yet still require a total of only two tubes.

2. Amplification at Intermediate Frequency

Intermediate-frequency amplifiers can operate with the fewest components if a basic design is chosen having one main unit to handle the sound by the intercarrier method. Stagger-tuned intermediate-frequency amplifier circuits have been quite popular during the past few years but are difficult to design for optimum adjacent-channel selectivity combined with good gain per stage. Measurements have shown that a modified bandpass-filter-coupled amplifier can give better adjacent-channel selectivity than stagger-tuned amplifiers and a sufficient increase in gain per stage to provide quite good operation with only three stages.

3. Video Detection

Video detectors are almost invariably of the single-diode type and are, therefore, about as simple as can be devised. We have found that a crystal diode, such as type 1N34, has some operating features which are a distinct improvement over available tube diodes. The crystal diode has low capacitance, linear output to low signal voltages, and is very easily wired into the circuit. It may be noted in passing that the high distortion which occurs in a sound AM receiver diode detector at modulations over 80 per cent is not a problem in a television receiver demodulator. This is due to the fact that the dc and ac loads are alike.

[1] H. Wallman, A. B. Macnee, and C. P. Gadsden, "A low-noise amplifier," PROC. I.R.E., vol. 36, pp. 700–708; June, 1948.

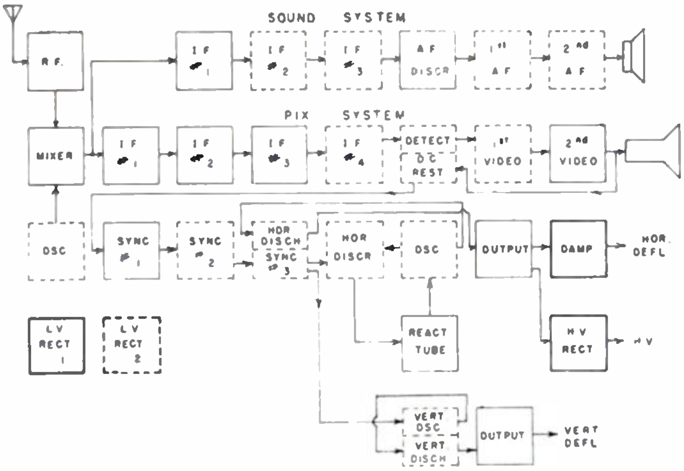

Fig. 1—Block diagram of a typical post-war good-quality receiver. Note—No AGC.

4. *Video Amplification*

The video signal for the picture tube could be supplied directly from the video detector if a high-level-output intermediate-frequency amplifier is chosen. This would also take care of the dc level. However, better gain-bandwidth figures are obtained in practice in a video amplifier than in an intermediate-frequency amplifier, and a large tube would have to be used in the final stage of the intermediate-frequency amplifier in order to supply 50 or more volts root-mean-square to the diode. Hence, a video amplifier having only one stage seems advisable. It is possible to design the video amplifier so that it takes care of the dc level control by the choice of a dc coupled circuit, provided that the reference dc point is stable during changes in amplitude of the received signal.

Maintenance of the dc level is most important, otherwise the background of the picture would change in intensity with change in the scene.

5. *Direct-Current Level Control*

Direct-current level control by the method of dc coupling the video amplifier eliminates the need of an extra diode and makes it possible to incorporate some noise limiting if the polarity of the video detector is suitably chosen.

6. *Gain Control*

It was realized that an automatic gain control circuit of good quality would be of major importance in receiver operation. A satisfactory automatic gain control (AGC) would lessen the need for adjusting the contrast control during tuning, would further stabilize the amplitude of pulses, and would avoid the overdrive and underdrive output settings of the manually operated receiver which can so often occur during switching of signals of widely different voltage levels. It was also known that simple types of automatic *volume* control circuits were inadequate since they responded directly to noise and interference voltages and also tended to upset the dc level control. Hence, the objective became a circuit which would produce a controlled voltage referred in amplitude to the black level of the signal.

7. *Sound Intermediate-Frequency Amplification*

The sound system which appears to give the greatest ease in tuning with a reasonably small number of components is the intercarrier system. With this type of operation it is usually permissible to employ only one stage of amplification at the frequency of 4.5 Mc. Aside from the adequacy of the single stage, there is greater ease in tuning the receiver since the fine tuning control is used only for obtaining the best picture quality and has little effect upon the sound. As has often been pointed out, there is the added freedom from the effect of local oscillator drift, oscillator tube microphonism, and hum.

8. *Discriminator*

The sound discriminator may be of various types. However, the ratio detector provides a relatively high audio-frequency output for the 25-kc FM deviation occurring in television sound operation and is reasonably stable in tuning.

9. *Audio Amplifier*

Preliminary analysis of the audio amplifier indicated that more than one stage is advisable. The usual procedure has been to use two separate tubes for this function. It appeared possible to combine this function with other portions of the receiver. As will be shown later, this has been tried out and a high degree of success has been obtained.

10. *Synchronizing Pulse Amplification and Separation*

Various types of synchronizing pulse amplifiers and separation circuits can be devised. The one chosen in this experimental work has no particular novelty except some reduction in the number of resistors. It seems that a double-triode tube should be sufficient for good synchronizing signal separation, especially if the input signal is obtained from the AGC peak voltage diode. This will be described at a later point.

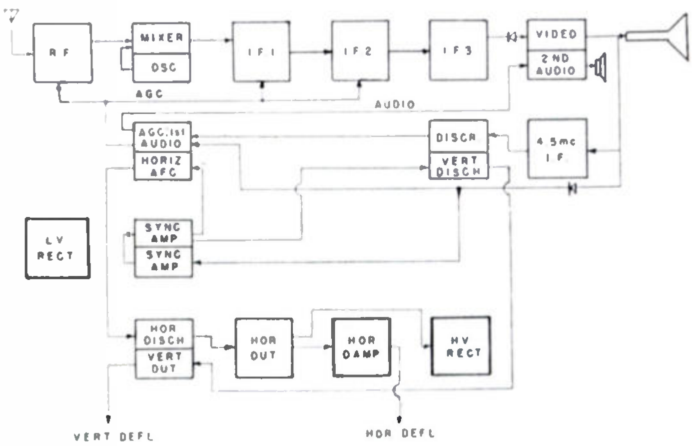

Fig. 2—Block diagram of a simplified receiver.

11. Horizontal Deflection

Horizontal deflection, preferably with automatic frequency control (AFC), is one function which lent itself to a considerable degree of simplification. Receivers have been constructed with four to eight tube sections to perform this operation. Clark[2] has called attention to the fact that there are three principal AFC circuits in use. These are the saw-tooth type, the sine-wave type, and the pulse-time type. The last one appears to require the smallest number of elements of those presently in use. Sufficient work has been done during the progress of this study to indicate that horizontal deflection with stable AFC might be obtained with a total of only two tubes.

12. Vertical Deflection

The status of vertical deflection has already attained considerable simplicity. Use of one double triode now appears sufficient for vertical deflection, including both saw-tooth generation and amplification.

13. High-Voltage Supply

Various sources of high voltage for a television receiver may be employed, for example, (a) a 60-cycle transformer, (b) a radio-frequency high-voltage supply, or (c) the horizontal-deflection amplifier pulse. Source (c) is most attractive for a number of reasons such as the following:

A. Very little shielding is required since the pulse is automatically in synchronism with the picture horizontal deflection.

B. There is a useful degree of automatic regulation of picture size as the line voltage varies.

C. The circuit is simple since it requires only the addition of a rectifier tube, filter resistor, and capacitor.

D. Finally, there is automatic protection of the picture tube if horizontal deflection fails.

14. Low-Voltage Supply

It should be pointed out that even the low-voltage power supply to a television receiver can be simplified. One item to be stressed is that, almost without exception, the rectifier choke has been placed in the positive side of low-voltage power supplies in television receivers. Tests show that there is no logical objection to putting the filter choke in the negative side, for example, from the center tap of the power transformer to ground. With this connection, the voltage drop across the choke and focus coil, if there is an electromagnetic focus coil, may be used for the negative dc supply, avoiding the use of a separate rectifier tube or the wasted voltage drop in an additional resistor which might be used in the return lead from the power transformer.

Dual Functions

Next comes the possibility of combining two functions in the same tube. Some of these possibilities have already been mentioned, such as the use of one double triode for the whole vertical deflection.

Thought was given to other possible combinations of functions, such as adapting a portion of the intermediate-frequency amplifier to serve also as the first sound amplifier, then using the AGC tube to serve also as part of the synchronizing circuit and, finally, to using the AGC tube to function also as the first audio amplifier.

The characteristics of various standard tubes were studied to see if one double-purpose tube could operate as the combined video amplifier and the final audio output stage.

The experimental part of the program was begun with measurements of the type 28D7 tube for its possible use in a combined audio-output stage and the whole video amplifier. These measurements showed that the tube had excellent characteristics as a video amplifier, operating with the cathode tied to ground and the control grid directly connected to a negatively polarized diode second detector. When dc coupled from the anode filter to the cathode of the picture tube, the voltage gain is 20 with a bandwidth of 4 Mc.

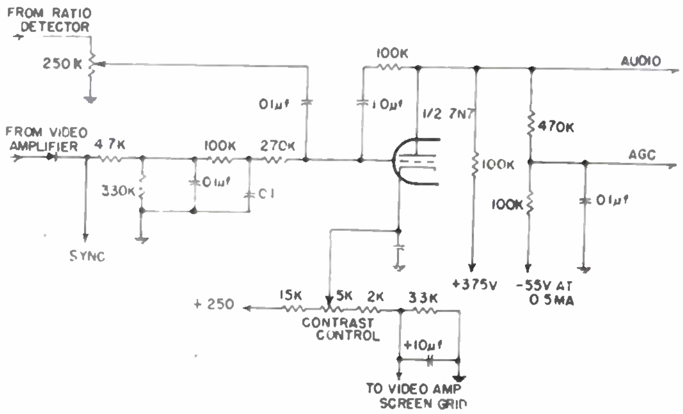

Fig. 3—Schematic of combined AGC and first audio amplifier using one half of a type-7N7 tube.

While one section of the tube is amplifying the video signal, the other section of the tube easily supplies 3 watts of audio power. These operating conditions are with a screen grid voltage of 33 and a total screen current of only 0.4 ma. Combining the video amplifier and audio output in a single tube means one less socket with correspondingly fewer pin connections.

One might be curious as to possible cross talk inside the tube envelope between the video and the audio signals. Careful measurements of a number of tubes show that the cross talk is quite low, averaging 70 db down.

We were interested in the possibility of combining the last intermediate-frequency amplifier and first audio stages. Measurements showed that this combination in the one tube has only one major objection—a high noise component in the received signal, particularly automobile ignition noise, will be superimposed upon the sound.

A new AGC circuit was developed for operating from the black-level voltage of the video signal with a negligibly small power consumption from the negative bias

[2] E. L. Clark, "Automatic frequency phase control of television sweep circuits," Proc. I.R.E., vol. 37, pp. 497–500; May, 1949.

supply. Thought was given to the possibility of also supplying some sync amplification. The first two items were attained by a new circuit which was developed during the experimental work and which is shown in Fig. 3. However, instead of combining the AGC with the sync amplifier, it was found to be, in general, preferable to make it serve the dual purpose of AGC and first audio amplifiers. In this way, one half of a type-7N7 double triode operates as a stable automatic-gain-control amplifier and, at the same time, as the first stage of the audio amplifier. The other half of the double tube can be used as part of the horizontal-deflection system.

Enough work has been done on a combined horizontal-deflection and automatic-frequency-control circuit to show the possibility of performing this combined function with fewer than 3 tubes. This work, however, has not yet been completed.

Simplification of the low-voltage power supply has resulted in one model which provides, from only one rectifier and a single filter choke, the main positive dc voltage and two negative voltages, one for the AGC amplifier divider, the other for biasing the final audio stage. The total filter capacitance is approximately one half that of conventional television receivers and the hum voltage is lower than that of any other television receiver that we have measured.

Additional items considered included the possible reduction in the number of resistors and capacitors in the synchronizing separation circuits. One result was a low-pass filter for the vertical integrating network having a total of two resistors and two capacitors which gave a steeper pulse output than older, more complex networks.

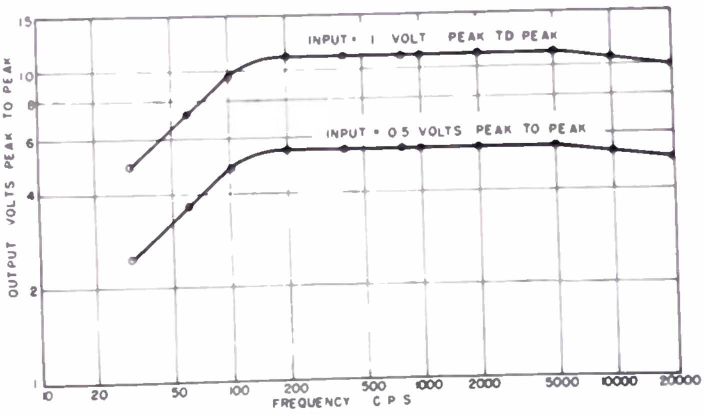

Fig. 4—Audio-frequency response curve of first audio and AGC

Description of Sample Receiver

Having briefly described some of the experiments performed to date, a short description will be given of a completed sample receiver incorporating some of the features described.

Fig. 1 is the block diagram of a type of circuit which was very popular in 1948. In this diagram, the rectangles with heavy boundaries represent the rectifiers and the rectangles with dotted outlines are of those sections which have been removed or combined with other functions in one of the simplified receivers. The fact that both stages of the audio amplifier have dotted outlines is due to their combination with other functions and not to the elimination of the audio amplifier. It should be noted that this receiver does not have automatic gain control.

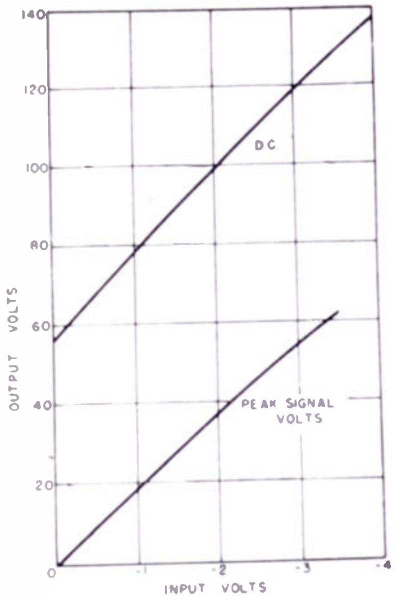

Fig. 5—Video gain characteristic of 28D7 tube, one section only. Zero-signal bias = 0, screen voltage = 33.

Fig. 2 shows the basic block diagram of a simplified receiver. The tuner uses a total of only two tubes, yet it has good image selectivity and a reasonably high signal-to-noise ratio. The intermediate-frequency amplifier has three stages of simple bandpass-filter coupling giving a voltage gain of 1,500. A tube similar to type 28D7 employing a 6.3-volt heater is used for the video amplifier and second stage of audio. For best operation a type-1N34 crystal is used as the second detector, although this could be replaced with one half of a type-6AL5 tube with some deterioration in operation. The intercarrier intermediate-frequency amplifier feeds the double-diode section of a type-7X7 or a 6T8 tube, while the triode section of this same tube produces the vertical sawtooth signal which is then amplified by one section of a 7N7, the other section of this latter tube providing the horizontal discharge for the horizontal-deflection amplifier stage. One section of another double triode operates as the combined AGC amplifier and first audio stage while the other section provides horizontal automatic frequency control. The synchronizing amplifier, as has been mentioned before, is one of several possible, circuits using a double triode, the design of this particular circuit being influenced by the plan for a minimum number of components.

Fig. 3 shows the detailed schematic of the combined AGC first audio unit.

Fig. 4 shows the audio-frequency response curve of

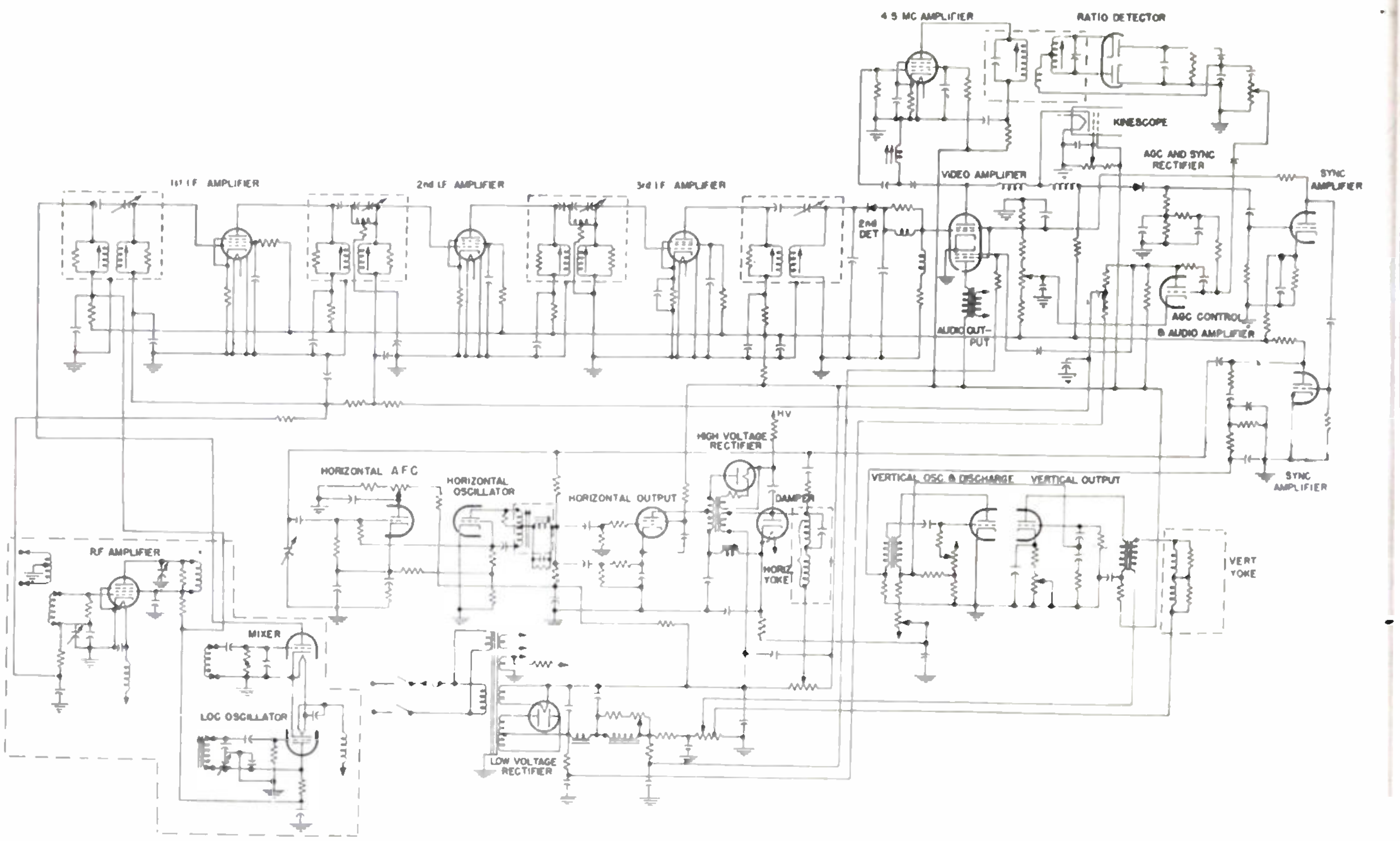

Fig. 6—Schematic of a complete simplified receiver.

the combined first audio and AGC amplifier. It will be noted that the frequency response is adequate for sound reproduction of reasonably high quality.

Fig. 5 shows the gain characteristic of one section of a type-28D7 tube used as a video amplifier.

Fig. 6 shows the over-all schematic for one of these receivers having 6 fewer tubes than the average good television receiver employing magnetic deflection. As mentioned previously, the two crystals could be replaced by one double-diode tube, although the improved operation obtained with the crystals and the simplicity in wiring would thereby be sacrificed.

Universal Design Curves for Intermediate-Frequency Amplifiers with Particular Reference to Phase and Amplitude Distortion and Their Compensation*

W. HACKETT†

Summary—The accurate assessment of distortion in intermediate-frequency amplifiers and the possibilities of compensation assume importance for the development of frequency-modulated very-high-frequency multi-channel equipment with its concomitant wide bandwidths. The present purpose is to furnish graphical data for the evaluation of phase and amplitude distortion arising from various types of coupling network including compensating combinations, to demonstrate a graphical procedure for accurate design, and to summarize the analysis on which the graphical treatment is based.

Sets of nomograms and curves provide for the assessment of performance as represented by gain times bandwidth, and for the interpretation of equation parameters in terms of circuit parameters.

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I. Introduction

For low harmonic distortion in frequency modulation systems, small amplitude and phase distortion, particularly the latter, are essential. The use of tuned circuits as the coupling networks in intermediate-frequency amplifiers gives rise to both types of distortion. The purpose of the present study is to provide data in graphical form to facilitate the design of intermediate-frequency amplifiers of sufficiently low distortion.

For wide bandwidths, small distortion requires relatively low Q circuits which will usually be achieved by the shunt connection of resistance. Attention has, therefore, been confined throughout to parallel-loaded tuned circuits. At the same time it has been assumed that the carrier frequency is located at the point of phase symmetry, which for parallel-loaded circuits occurs at a frequency slightly different from the resonant frequency and requires some detuning.

For coupling networks comprising either single- or coupled-tuned circuits, a rigorous treatment leads to complicated equations for phase and amplitude distortion. Simple approximate equations are given which can be shown to represent phase distortion to a high degree of accuracy and amplitude distortion to a rather lower degree of accuracy for a single-tuned circuit. It is then shown that, under certain conditions, one stage comprising a pair of coupled-tuned circuits is substantially equivalent in respect of distortion to two stages of single-tuned circuits in which the resonant frequencies are staggered above and below the carrier frequency. This equivalence leads to the derivation of relatively simple, approximate equations for the distortion arising from coupled-tuned circuits in terms of equation parameters which differ somewhat from those adopted for series-loaded circuits or circuits of high Q.[1-3]

It is known that, over a certain range of parameters, coupled circuits exhibit amplitude and phase distortion of opposite sign to those obtaining with single-tuned circuits. This fact may be utilized to achieve a considerable measure of compensation by the cascade connection of stages embodying single- and coupled- or staggered-tuned circuits when the circuit parameters are suitably chosen. The requirement is therefore to present the data for the two characteristic types of distortion in such a form as to assist the optimum choice of parameters and permit the quantitative assessment of distortion in compensating combinations.

II. List of Symbols

$A = [-jk\, 2\pi f_{rc}^2 (C_1 C_2)^{1/2}]/f(1-k^2)$ (equation (10))

C = capacitance of tuned circuits in farads

C_e = equivalent capacitance per stage of unit network in farads

D_a = amplitude distortion per unit network in decibels

D_p = phase distortion per unit network

f = frequency in cps

f_0 = carrier frequency in cps

f_1, f_u = lower and upper values of f corresponding to given amplitude distortion for single-tuned circuits as rigorously derived

f_r = resonant frequency of tuned circuit in cps

Δf_r = error in f_r

F_e = equivalent gain factor per stage of unit network

g = mutual conductance of tube in amperes per volt

G = stage gain

G_e = mean or equivalent gain per stage of unit network

$J = K_1/2Q_s$

k = coefficient of coupling

k_c = coefficient of critical coupling

$K_1 = Q_c[(1-k)^{-1/2}+(1+k)^{-1/2}]$ for coupled-tuned circuits,

$= Q_2 + Q_1$ for staggered-tuned circuits

$K_2 = Q_c[(1-k)^{-1/2}-(1+k)^{-1/2}]$ for coupled-tuned circuits,

$= Q_2 - Q_1$ for staggered-tuned circuits

n_s = number of stages per unit network

n_u = number of unit networks

Q = magnification factor of tuned circuit at resonant frequency

$x = F_e(f-f_0)/f_0$

Z = transfer impedance of coupling network of one stage

Z_e = equivalent transfer impedance per stage of unit network

$\lambda = K_1(f-f_0)/f_0$

$\Delta\lambda$ = error in λ corresponding to error Δf_r

λ_a = value of λ corresponding to peak values of D_a (Fig. 2)

λ_p = value of λ corresponding to peak values of D_p (Fig. 1)

ϕ = phase shift associated with unit network

ϕ_0 = value of ϕ at $f=f_0$.

TABLE I

Suffixes	Refer to
1, 2	Individual equivalent and/or actual tuned circuits involved in coupled or staggered circuit networks.
c	Coupled-tuned circuits.
s	Single-tuned circuits.
st	Staggered-tuned circuits.
s/c	Compensating combination comprising single- and coupled-tuned circuits.
s/st	Compensating combination comprising single- and staggered-tuned circuits.

[1] K. R. Sturley, "Radio Receiver Design," Chapman and Hall, London, England, Part I: p. 301, Part II: p. 377; 1947.

[2] R. T. Beatty, "Two-element band-pass filters," *Wireless Eng.*, vol. 9, p. 546; October, 1932.

[3] R. T. Beatty, "Radio data charts" (4th edition, revised by J. M. Sowerby), Iliffe, London, England, p. 41; 1945.

III. Definitions

Unit Network

It is found convenient to define and express distortion in terms of the "unit network," which is defined as the smallest repeatable combination of stages n_s in the amplifier.

Performance Parameter P

Assuming a constant current source such as a pentode, the ratio of output to input voltage of an amplifier stage is given by gZ, where g is the mutual conductance of the tube and Z is the transfer impedance of the coupling network. The stage gain G at the carrier frequency f_0 is then given by

$$G = g\,|Z|_{f=f_0}.$$

If the n_s stages of a unit network have transfer impedances $Z_1, Z_2 \cdots Z_{n_s}$, then the mean or equivalent gain per stage G_e at the carrier frequency is given by

$$G_e = g\,|Z_e|_{f=f_0}$$

where

$$Z_e = \prod_{n=1}^{n_s} Z_n^{1/n_s}.$$

It can be shown that G_e is of the form

$$G_e = \frac{g}{2\pi f_0 C_e} F_e \tag{1}$$

where

C_e = equivalent capacitance per stage
F_e = equivalent gain factor per stage

and both C_e and F_e depend on the type of unit network. If the performance parameter P is defined as equivalent gain per stage times fractional half bandwidth, then

$$P = G_e\left(\frac{f-f_0}{f_0}\right) = \frac{gx}{2\pi f_0 C_e} \tag{2a}$$

where

$$x = F_e\left(\frac{f-f_0}{f_0}\right). \tag{2b}$$

Amplitude Distortion

The amplitude distortion associated with a unit network D_a may be defined as the ratio of the modulus of the output voltage at frequency f to that at carrier frequency f_0, expressed as an attenuation in decibels, and is given by

$$D_a = 20n_s[\log_{10}|Z_e|_{f=f_0} - \log_{10}|Z_e|]. \tag{3}$$

Phase Distortion

The phase distortion associated with a unit network D_p may be defined as the difference between the actual phase shift ϕ at frequency f and that which would obtain if the phase-shift frequency gradient were constant at the carrier frequency value, i.e.,

$$D_p = \phi - \phi_0 - (f-f_0)\left(\frac{d\phi}{df}\right)_{f=f_0}. \tag{4}$$

IV. Formulas for Phase and Amplitude Distortion

A. Single-Tuned Circuit

The transfer impedance Z_s for a parallel-loaded tuned circuit is given by

$$Z_s = \frac{1}{2\pi f_{rs} C_s\left[\frac{1}{Q_s} + j\left(\frac{f}{f_{rs}} - \frac{f_{rs}}{f}\right)\right]} \tag{5}$$

where

f_{rs} = resonant frequency
Q_s = circuit Q
C_s = capacitance of tuned circuit.

The derived phase-frequency characteristic shows a point of inflection, which is a point of skew symmetry, at a frequency slightly lower than f_{rs}. Assuming that the circuit is so tuned as to locate the carrier frequency f_0 at the point of phase symmetry, it can be shown that the phase distortion per stage in radians is given to a very close approximation by

$$D_{ps} = 2Q_s\left(\frac{f-f_0}{f_0}\right) - \arctan\left[2Q_s\left(\frac{f-f_0}{f_0}\right)\right] \tag{6a}$$

which may be expressed in the form

$$D_{ps} = \frac{\lambda}{J} - \arctan\left(\frac{\lambda}{J}\right) \tag{6b}$$

where

$$\lambda = K_1\left(\frac{f-f_0}{f_0}\right) \tag{6c}$$

and

$$J = K_1/2Q_s, \tag{6d}$$

and is a scale-adjusting factor used in Section IVD for the determination of the conditions for compensation. The curve of D_{ps} is skew symmetrical about $\lambda = 0$, i.e., $f = f_0$, and is positive for positive values of λ.

The amplitude distortion per stage D_{as} is then given approximately by

$$D_{as} = 10\log_{10}\left[1 + \left\{2Q_s\left(\frac{f-f_0}{f_0}\right)\right\}^2\right] \tag{7a}$$

which may be expressed in the form

$$D_{as} = 10\log_{10}\left[1 + \left(\frac{\lambda}{J}\right)^2\right]. \tag{7b}$$

Whereas D_{as} as given by (7) is symmetrical about $\lambda=0$, i.e., $f=f_0$, a rigorous analysis, while giving substantially the same bandwidth for the same distortion, requires the band to be displaced towards the higher frequencies. The approximate symmetrical equation will usually be sufficiently accurate for general design purposes, but corrections may be applied as a refinement if required. If for a particular value of distortion the symmetrical curve gives a fractional bandwidth of $2(f-f_0)/f_0$, and the true upper and lower frequencies as rigorously derived are f_u and f_l, respectively, then the true fractional bandwidth is given by

$$\frac{f_u - f_l}{f_0} = \frac{f_{rs}}{f_0}\left[\frac{2\,(f - f_0)}{f_0}\right] \tag{8}$$

and the deviation of its midpoint from the carrier frequency is given by

$$\frac{\{(f_u + f_l)/2\} - f_0}{f_0} = \frac{f_{rs}}{f_0}\left[1 + \left(\frac{f - f_0}{f_0}\right)^2\right]^{1/2} - 1$$

$$\simeq \frac{f_{rs} - f_0}{f_0} + \frac{1}{2}\left(\frac{f - f_0}{f_0}\right)^2 \tag{9}$$

where f_{rs} is given by (29) of Table III and is an inverse function of Q_s.

B. Coupled-Tuned Circuits

It can be shown that the transfer impedance Z_c associated with a pair of coupled circuits, which are tuned to the same frequency f_{rc} and are of equal Q, can be expressed in the form

$$Z_c = AZ_{s1}Z_{s2} \tag{10}$$

where

$$A = \frac{-jk2\pi f_{rc}^2(C_1C_2)^{1/2}}{f(1 - k^2)} \tag{10a}$$

$$Z_{s1} = \frac{1}{2\pi f_{r1}C_1\left\{\dfrac{1}{Q_1} + j\left(\dfrac{f}{f_{r1}} - \dfrac{f_{r1}}{f}\right)\right\}} \tag{10b}$$

$$Z_{s2} = \frac{1}{2\pi f_{r2}C_2\left\{\dfrac{1}{Q_2} + j\left(\dfrac{f}{f_{r2}} - \dfrac{f_{r2}}{f}\right)\right\}} \tag{10c}$$

$$f_{r1} = f_{rc}/(1 + k)^{1/2} \tag{10d}$$

$$f_{r2} = f_{rc}/(1 - k)^{1/2} \tag{10e}$$

$$Q_1 = Q_c/(1 + k)^{1/2} \tag{10f}$$

$$Q_2 = Q_c/(1 - k)^{1/2} \tag{10g}$$

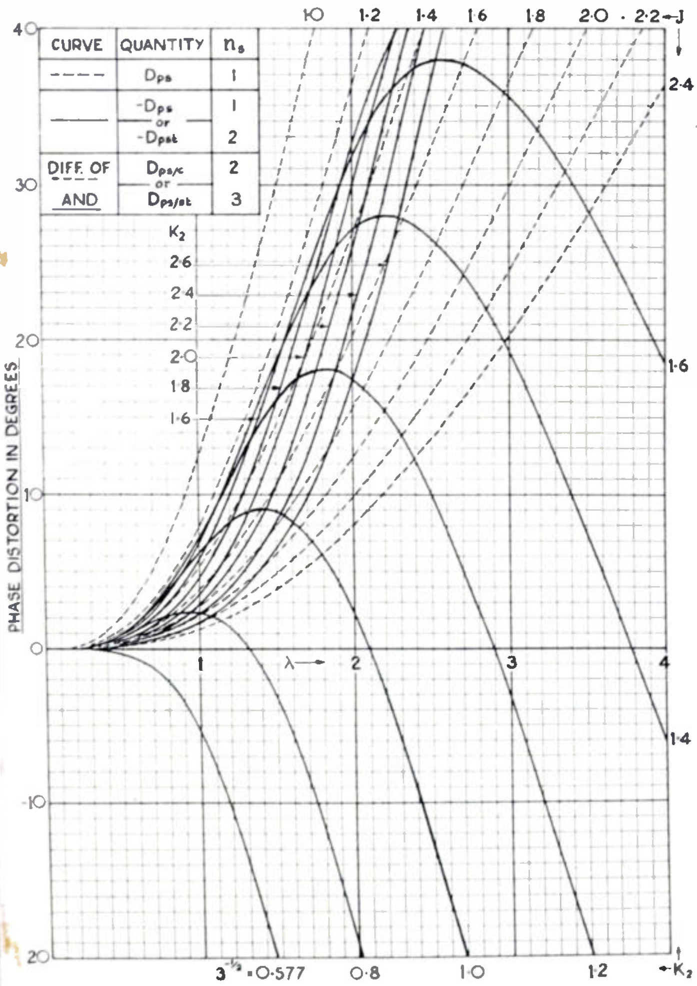

Fig. 1—Phase distortion for simple unit networks and derived compensating combinations.

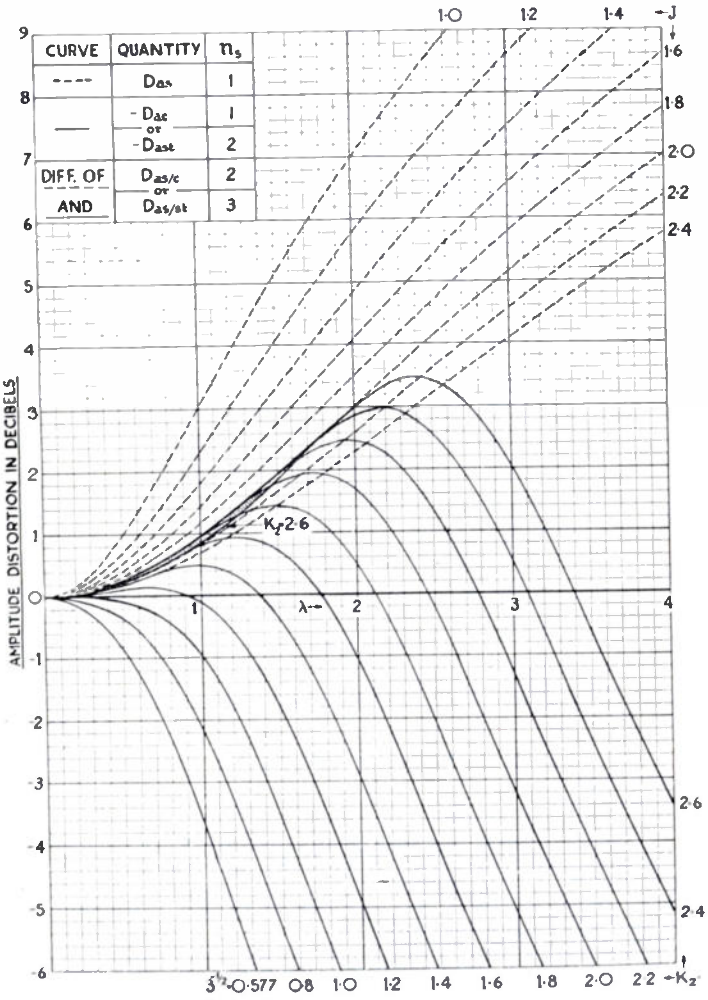

Fig. 2—Amplitude distortion for simple unit networks and derived compensating combinations.

$Q_c = Q$ value of coupled circuits
k = coupling coefficient
C_1, C_2 = capacitances of coupled circuits.

Comparison with (5) indicates that Z_c is equivalent to A times the product of the impedances of two single resonant circuits, which have the same product of capacitance into shunt resistance and are tuned respectively to f_{r1} and f_{r2}.[4-5] Factor A is an inverse function of frequency and includes a phase shift of $-90°$.

The phase-frequency characteristic of coupled circuits shows a point of inflection which is a point of skew symmetry at a frequency slightly greater than the resonant frequency. If the resonant frequency is so adjusted that the point of phase symmetry is coincident with the carrier frequency f_0, derivation from (6) gives approximately for the phase distortion D_{pc} of coupled circuits

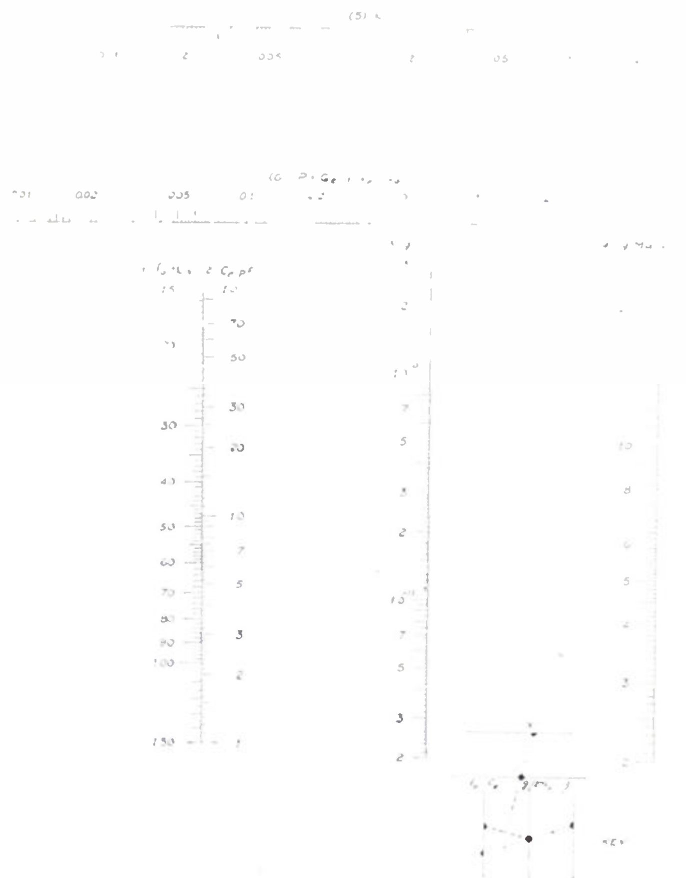

Fig. 3—Nomogram for performance parameter P. $P = G_c\left(\frac{f-f_0}{f_0}\right) = \frac{gx}{2\pi f_0 C_e}$. For C_e see Table II and Fig. 4. For x see Table II and Fig. 5.

[4] This equivalence has been pointed out by E. A. Guilleman "Communication Networks," John Wiley and Sons, New York, N. Y., vol. 1, p. 324; 1946, for the case of identical coupled-tuned circuits. As shown above, the condition of identity is unnecessary, provided that the Q values are equal.

[5] The resonant frequencies f_{r1} and f_{r2} are equal respectively to the two natural resonant frequencies associated with coupled circuits of negligible damping. See G. W. O. Howe, "Analysis of frequency in oscillatory circuits," *Elec. World*, vol. 68, pp. 368–370; August 19, 1916. See also G. W. O. Howe, "Bandpass filters in radio receivers," *Experimental Wireless*, vol. 8, pp. 233–237; May, 1931.

$$D_{pc} = \frac{2\lambda}{1 + K_2^2} - \arctan(\lambda + K_2) - \arctan(\lambda - K_2)$$
$$= \frac{2\lambda}{1 + K_2^2} - \arctan\left(\frac{2\lambda}{1 + K_2^2 - \lambda^2}\right) \quad (11)$$

where

$$\lambda = K_1\left(\frac{f - f_0}{f_0}\right) \quad (11a)$$

$$K_1 = Q_c\left[(1 - k)^{1/2} + (1 + k)^{1/2}\right]$$
$$\cong 2Q_c \text{ for small values of } k \quad (11b)$$

$$K_2 = Q_c\left[(1 - k)^{-1/2} - (1 + k)^{-1/2}\right]$$
$$\cong Q_c k \text{ for small values of } k$$
$$\cong k/k_c \text{ for large values of } Q_c \quad (11c)$$

k = coefficient of coupling
k_c = coefficient of critical coupling.

D_{pc} is skew symmetrical about $\lambda = 0$, i.e., $f = f_0$, and is negative for positive values of λ over a certain range depending on the value of $K_2 > 1/\sqrt{3}$, beyond which it becomes positive. The position λ_p of the peaks is given by

$$\lambda_p = \pm (3K_2^2 - 1)^{1/2}. \quad (12)$$

A rigorous analysis gives curves for amplitude distortion which are symmetrical about f_0, f in the denominator of factor A of (10a) correcting for the inherent asymmetry associated with the equivalent single-tuned circuits. Thus, by adopting the approximate symmetrical equation (7) for single-tuned circuits and regarding f in factor A as constant, D_{ac} for coupled circuits can be shown to be given to a very close approximation by

$$D_{ac} = 10 \log_{10}\left[(1 + K_2^2 - \lambda^2)^2 + 4\lambda^2\right]$$
$$- 20 \log_{10}\left[1 + K_2^2\right]. \quad (13)$$

Critical coupling corresponds to $K_2 = 1$, above which the characteristic exhibits the familiar double hump, the peak values of which occur at λ_a given by

$$\lambda_a = \pm (K_2^2 - 1)^{1/2}. \quad (14)$$

Equations (11) and (13) show that phase distortion D_{pc} and amplitude distortion D_{ac} can each be represented completely in terms of the two parameters λ and K_2, and therefore by a single family of curves plotted against λ for different values of K_2 as illustrated by the full-line curves of Figs. 1 and 2. This is not possible, except for high values of Q, where the more usual parameters[1-3] $Q(f - f_0)/f_0$ and k/k_c are used.

C. Staggered-Tuned Circuits

For two stages of single resonant circuits tuned to frequencies f_{r1} and f_{r2} respectively, and having Q values Q_1 and Q_2 at these frequencies, the product of the transfer impedances is given by

$$Z_{s1} \times Z_{s2} = Z_{st}^2 \tag{15}$$

where Z_{s1} and Z_{s2} are of the form of (10b) and (10c), respectively. If the circuits have the same product of capacitance into shunt resistance so that

$$\frac{Q_1}{f_{r1}} = \frac{Q_2}{f_{r2}} \tag{16}$$

and are so tuned that the carrier frequency coincides with the point of skew symmetry of the resultant phase-shift characteristic, then the phase distortion D_{pst} for two stages of staggered circuits is given as for one stage of coupled-tuned circuits by (11) where

$$K_1 = Q_2 + Q_1 \tag{17a}$$

$$K_2 = Q_2 - Q_1. \tag{17b}$$

In this case, owing to the absence of a factor A with its correcting factor f, there will in practice be some asymmetry in the amplitude characteristic. For general design purposes, however, it is convenient to assume symmetry so that amplitude distortion D_{ast} for two stages of staggered circuits may be represented approximately by the same equation (13) as for a single stage of coupled-tuned circuits.

It is evident that the replacement of one stage of coupled-tuned circuits by two stages of staggered-tuned circuits offers the possibility of higher gain for the same distortion while at the same time affording greater facility of adjustment.

D. Compensating Combinations

The difference in sign of the phase and amplitude distortion associated with single- and coupled- or staggered-tuned circuits can be utilized to give a considerable measure of compensation over a range of λ, provided that certain relations obtain between the parameters J and K_2. Curves for phase and amplitude distortion are presented in Figs. 1 and 2 respectively in such a form as to reveal the appropriate relations. The broken line curves represent distortion arising from a single-tuned circuit, D_{ps} and D_{as}, as a function of λ for different values of J. The full line curves, on the other hand, show the mirror image of the distortion associated with a unit network of the coupled or staggered circuit type, i.e. $(-D_{pc})$ or $(-D_{pst})$ in Fig. 1 and $(-D_{ac})$ or $(-D_{ast})$

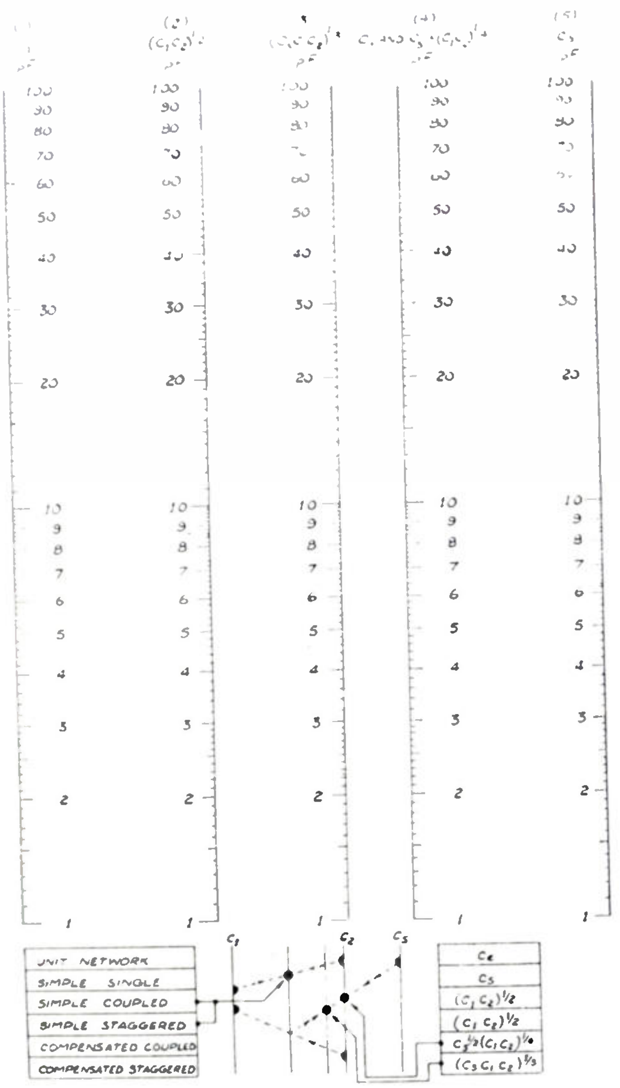

Fig. 4—Nomograms for equivalent capacitance C_e for simple and compensating unit networks.

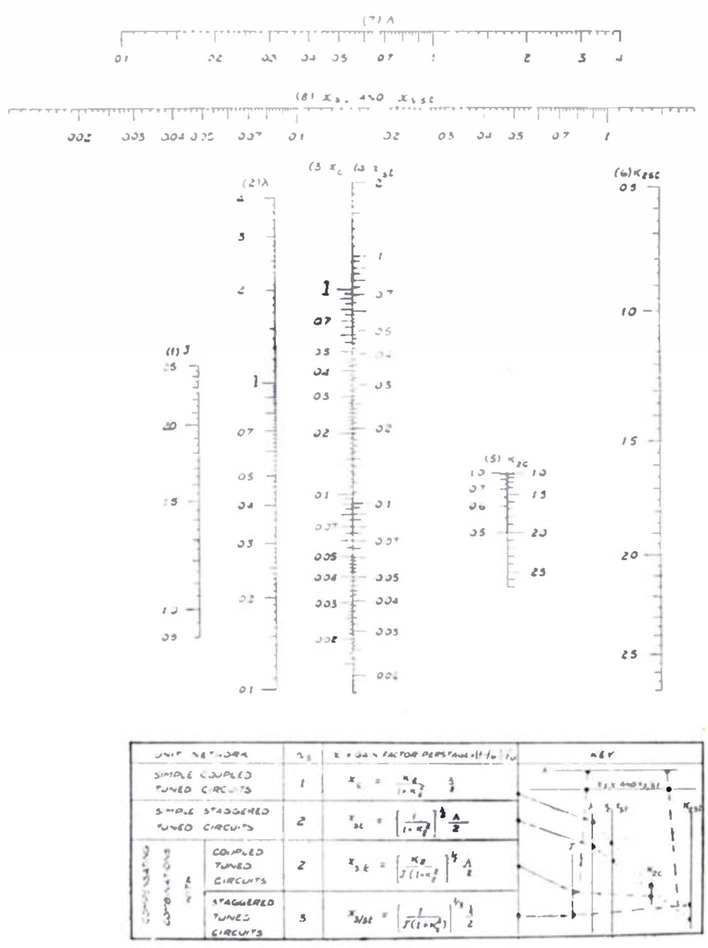

Fig. 5—Nomograms for conversion from λ to x for simple and compensating unit networks.

in Fig. 2, as a function of λ for different values of K_2.[6] Since both phase and amplitude distortion arising from a number of unit networks add algebraically, the difference between any J and any K_2 curve gives the resultant distortion $D_{ps/c}$, $D_{as/c}$, $D_{ps/st}$ or $D_{as/st}$ for the corresponding compensating unit network.

It is to be noted that equal increments of J correspond to equal increments of λ for the same distortion, which permits linear interpolation for intermediate values of J. Since $J = K_1/2Q_s$, K_1 ≅ $2Q_c$ for coupled circuits and $K_1 = (Q_1+Q_2)$ for staggered circuits, J represents approximately the ratio of the Q of coupled circuits or the mean Q of staggered circuits to that for the single-tuned circuit.

It is apparent from Fig. 2 that maximum compensation for amplitude distortion requires a value of J of the order of 2, which may not necessarily represent the optimum value for compensation of phase distortion, and some compromise may be required. For special purpose where both phase and amplitude distortion are required to be very small, a better compromise may be possibly achieved by the use of more complicated compensating combinations involving three or more simple unit networks, e.g., one of the single-tuned circuit type and two of the coupled- or staggered-tuned circuit types. Mathematical treatment is difficult but design can conveniently be carried out by trial and error, using the curves of Figs. 1 and 2. It may be found convenient to use different equation parameters (K_1 and K_2) for unit networks of similar type; the values of D_p and D_a corresponding to a given frequency deviation must then be derived for different values of $\lambda = K_1(f-f_0)/f_0$ in the two cases.

[6] Intersection and close proximity preclude the separate delineation of the D_{ac} curves for $K_2 = 1.4$ to 2.4 at low values of λ. They all fall within the cross-hatched area and are of the same general form as the curve for $K_2 = 2.6$, which follows the lower boundary.

V. Evaluation of Performance Parameter P

To compare the merits of different circuit arrangements it is necessary to interpret λ in terms of performance parameter P, i.e., equivalent gain per stage at car-

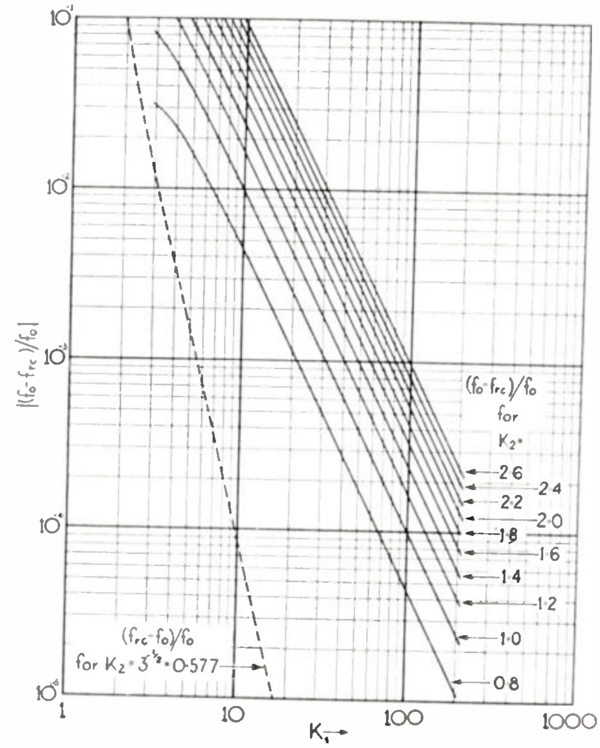

Fig. 7—Resonant frequency of coupled-tuned circuits in terms of equation parameters.

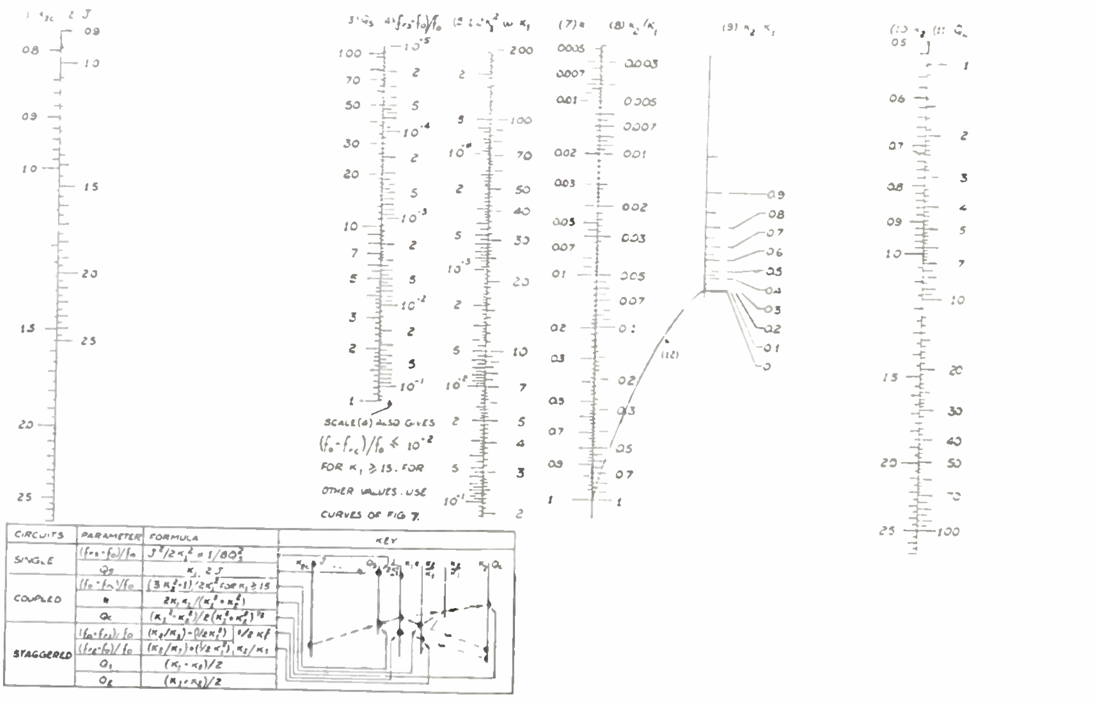

Fig. 6—Nomograms for conversion from equation to circuit parameters for single-, coupled-, and staggered-tuned circuits.

rier frequency times fractional semibandwidth, which is given by (2) and may be evaluated by the nomogram of Fig. 3, using a set-square index.[7]

This formula involves C_e, the equivalent capacitance per stage and x, the equivalent gain factor per stage times fractional half bandwidth. Both factors are given for specific unit networks by the equations of Table II and may be evaluated from the nomograms of Figs. 4 and 5 respectively. For more complicated combinations, C_e and x are given by the geometric mean of the values of C_e and x associated with the component stages.

[7] H. J. Allcock and J. R. Jones, "The Nomogram," Pitman, London, England, chap. 4, 1946.

VI. Conversion from Equation Parameters to Circuit Parameters

The required circuit parameters are resonant frequencies, Q values, and for coupled circuits, coefficient of coupling. They are given for the three basic unit networks by the conversion equations of Table III and may be evaluated from the nomograms of Fig. 6 and curves of Fig. 7.

Error in the tuning of the resonant circuits will give rise to asymmetry in the distortion characteristics of Figs. 1 and 2. A positive error Δf_r in the resonant frequency of single- or coupled-tuned circuits or in the mean resonant frequency of staggered-tuned circuits will cause a shift to the right by an amount $\Delta\lambda\Omega K_1\Delta f_r/f_0$.

TABLE II

Equations for Evaluation of Factors Involved in Performance Parameter for Various Unit Networks

Unit Network		Number of Stages n_s	Equation[1] Factor	Expression	Number
Single tuned circuit		1	C_e	C_s	(18)
			x_s	$\frac{\lambda}{2J}$ [2]	(19)
				$=\frac{\lambda}{2}$ for $J=1$	(19a)
Coupled tuned circuits		1	C_e	$(C_1C_2)^{1/2}$	(20)
			x_c	$\frac{K_2}{1+K_2^2}\cdot\frac{\lambda}{2}$	(21)
Staggered-tuned circuits		2	C_e	$(C_1C_2)^{1/2}$	(22)
			x_{st}	$\frac{1}{(1+K_2^2)^{1/2}}\cdot\frac{\lambda}{2}$ [3]	(23)
Compensating combinations comprising	Single-tuned circuit, Coupled-tuned circuits	1, 1 (2)	C_e	$C_s^{1/2}(C_1C_2)^{1/4}$	(24)
			$x_{s/c}$	$\left[\frac{K_2}{J(1+K_2^2)}\right]^{1/2}\cdot\frac{\lambda}{2}$ [4]	(25)
	Single-tuned circuit, Staggered-tuned circuits	1, 2 (3)	C_e	$(C_sC_1C_2)^{1/3}$	(26)
			$x_{s/st}$	$\left[\frac{1}{J(1+K_2^2)}\right]^{1/2}\cdot\frac{\lambda}{2}$ [5]	(27)

[1] Equations (20), (22), (24), and (26) may be evaluated from Fig. 4 and (21), (23), (25), and (27) from Fig. 5.

[2] The gain factor included in x_s is strictly that at the resonant and not the carrier frequency, but the difference is negligible for practical purposes.

[3] This equation is correct to within 1 per cent for $K_1 \geq 7$; for other values of K_1 there will be slight errors.

[4] This equation involves the limitations of footnote 2 above.

[5] This equation involves the limitations of footnotes 2 and 3 above.

VII. Computing Procedure Illustrated by Numerical Examples

The computing procedure for the design of intermediate-frequency amplifiers for minimum distortion, when the bandwidth and over-all gain are specified, is outlined in Table IV and illustrated by two numerical examples for compensating unit networks of the coupled and staggered circuit types respectively.

The alternative case, when the maximum distortion is specified and it is required to design for maximum gain times bandwidth, can equally well be treated by a revised order of steps.

VIII. Conclusions

To meet the desiderata of wide bandwidths and low phase distortion, parallel loading of resonant circuits used as coupling networks has been assumed, together with the requisite detuning to locate the point of phase symmetry at the carrier frequency.

Simple approximate equations are given for the distortion associated with a single-tuned circuit, and corrections, which may be applied as a refinement, are indicated. For a unit network comprising one stage of coupled-tuned circuits of equal Q or its distortion equivalent of two stages of staggered-tuned circuits, the adoption of novel parameters leads to relatively simple equations for phase and amplitude distortion, each of which may then be represented by a single family of curves. Such representation permits advantage to be taken of the difference in sign of the distortion associated with single- and coupled- or staggered-tuned circuits over a certain range of parameters, to design compensating combinations.

TABLE III

Equations for Conversion from Equation to Circuit Parameters for Various Coupling Networks

$$K_1 = \lambda'\left(\frac{f-f_0}{f_0}\right) \qquad (28)$$

Coupling Network	Circuit Parameter	Conversion Formula: Expression	Conversion Formula: Number
Single-tuned circuit	$\frac{f_{rs}-f_0}{f_0}$	$\left[2\left(1-\frac{J^2}{K_1^2}\right)^{1/2}-1\right]^{1/2}-1$ $\simeq \frac{J^2}{2K_1^2} = \frac{1}{8Q_s^2}$ for $\frac{f_{rs}-f_0}{f_0} \leq 0.01$	(29)
	Q_s	$\frac{K_1}{2J}$	(30)
Coupled-tuned circuits	$\frac{f_0-f_{rc}}{f_0}$	$1-\frac{2Q_c}{K_1\left[\left(4-\frac{1}{Q_c^2}\right)^{1/2}-1\right]^{1/2}}$	(31)
		$\simeq \frac{3K_2^2-1}{2K_1^2}$ for $K_1 \geq 15$	(31a)
	k	$\frac{2K_1K_2}{K_1^2+K_2^2}$	(32)
	Q_c	$\frac{K_1^2-K_2^2}{2(K_1^2+K_2^2)^{1/2}}$	(33)
Staggered-single-tuned circuits	$\frac{f_0-f_{r1}}{f_0}$	$\frac{K_2}{K_1}-\frac{1}{2K_1^2}$ for $K_1>4$	(34)
	$\frac{f_{r2}-f_0}{f_0}$	$\frac{K_2}{K_1}+\frac{1}{2K_1^2}$ for $K_1>4$	(35)
	Q_1	$\frac{K_1-K_2}{2}$	(36)
	Q_2	$\frac{K_1+K_2}{2}$	(37)

Note—Equations (29), (30), (31a), and (32) through (35) may be evaluated from the nomograms of Fig. 6. For $K_1<15$ and $(f_0-f_{rc})/f_0>0.01$ use should be made of (31) which may be evaluated from the curves of Fig. 7.

Sets of nomograms and curves provide for the evaluation of the performance parameter (equivalent gain per stage times fractional semibandwidth) in terms of the tube mutual conductance, equivalent shunt capacitance, carrier frequency, and equation parameters, and for the conversion from equation to circuit parameters (resonant frequencies, Q values, coupling coefficient) for the various unit networks. The procedure for using the graphical data is indicated and illustrated by two numerical examples.

IX. Acknowledgments

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TABLE IV

Computation of Distortion and Circuit Parameters for Typical Compensated Unit Networks to Give Specified Over-all Gain and Bandwidth

Specified over-all gain $= 10^5$

Specified bandwidth $= \pm 1$ Mc $\left\} \frac{f-f_0}{f_0} = \frac{1}{30}\right.$

Specified carrier frequency $=$ 30 Mc

Assumed g $=$ 5 mA/V $\left\} \frac{g}{2\pi f_0} = 2.65 \times 10^{-11}.\right.$

Step	Quantity		Equation	Fig.	Compensating Combinations	
1	Unit network	Coupling circuit Number of stages n_s			Single 1 + Coupled 1	Single 1 + Staggered 2
	Associated capacitances	C_s pF C_1 pF C_2 pF			15 7.5 12.5	15 13.5 16.5
2	Equivalent capacitance C_e pF		(24) (26)	4 4	12	14.95
3	Number of unit networks n_u Total number of stages $n_u \cdot n_s$				2 4	1 3
4	Equivalent gain per stage G_e				$10^{5/4}$	$10^{5/3}$
5	$P=G_e(f-f_0)/f_0$				0.5925	0.718
6	x		(2a)	3	0.265	0.40
7	Selected values of	J K_2		1, 2	1.4 1.6	1.25 1.20
8	λ		(25) (27)	5 5	0.94	1.16
9	D_p (per unit network) degrees D_a (per unit network) db $n_u D_p$ degrees $n_u D_a$ db			1 2	−0.2 0.85 −0.4 1.7	0.2 3.1 0.2 3.1
10	K_1		(28)		28.20	34.8
11	Single-tuned circuit	$(f_{rs}-f_0)/f_0$ Q_s	(29) (30)	6 6	1.22×10^{-3} 10.1	6.5×10^{-4} 13.9
	Coupled-tuned circuit	$(f_0-f_{rc})/f_0$ k Q_c	(31a) (32) (33)	6 6 6	4.2×10^{-3} 0.113 14.1	
	Staggered-tuned circuit	K_2/K_1 $1/2K_1^2$		6		3.42×10^{-2} 4.1×10^{-4}
		$(f_0-f_{r1})/f_0$ $(f_{r2}-f_0)/f_0$ Q_1 Q_2	(34) (35) (36) (37)			3.38×10^{-2} 3.46×10^{-2} 16.8 18.0

Marginal Checking as an Aid to Computer Reliability*

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Summary—**Deteriorating components, particularly crystals and vacuum tubes, cause reduction of safety margins and are a principal source of error in digital computing and pulse communication.**

Marginal checking varies voltages in logical circuit groups, inducing inferior parts to cause failure, while a test program or pulse transmission detects and localizes potential failure. In a digital computer, this can be automatically accomplished with the computer itself acting as the detector.

In one trial on a 400-tube prototype system the application of this type of preventive maintenance for half an hour per day improved reliability 50 to 1. Results of preliminary tests on a full computer are discussed.

I. Introduction

Electronic digital computers will be used to solve real-time problems and must be reliable. For example, when the modern computer becomes the nerve center of an all-weather air traffic control system, the plane pilot must know the system is operating, and will continue to operate, without error. Such reliability can be guaranteed only by detecting imminent failures and preventing their occurrence.

In order to obtain "computer reliability," a much higher degree of performance is required than in ordinary means of communication. The basic difference is the high concentration of information used in a computer compared with the concentration of information in speech, television, or radar. Interruptions in circuits of the latter type can occur at frequent intervals, with little loss of intelligence. An occasional intermittent tube does not void the sense from a radio, ignition noise does not completely void television, nor does an arcing magnetron nullify the plot on a radar screen.

This criterion is not good enough in computer applications. The usual method of transmitting intelligence in a computer is to supply high-frequency pulses to particular circuits at specified times. A single pulse occurring at the wrong time can invalidate the usefulness of the whole effort. This single-error limitation is due to the presence of a memory in a computer. Memory remembers the errors as well as the information to be processed, and once an error becomes imbedded in the memory it can be propagated into all subsequent calculation.

The necessary reliability can be approached by combining good design with the best available components, and utilizing marginal checking as an additional aid.

Marginal checking differs from ordinary checking by not only answering the question, "Are all circuits functioning?" but also, "How much *longer* will the circuits function?" Good equipment starts with wide safety margins, but age and wear reduce these safety margins, leading to eventual failure. Marginal checking assures adequate safety by testing the system frequently enough so that only slight deterioration can occur between tests.

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II. The Marginal Checking System

A. Magnitude of the Problem

Most of the large-scale digital machines under development utilize many thousands of vacuum tubes, crystals, resistors, condensers, and coils. The vacuum tube is the least reliable component of this group, and the crystal rectifier, though better than the tube, is still a weak link in the chain of reliability. Failures in the resistors, condensers, and coils are not frequent, and these elements do not threaten computer reliability to such an extent.

What may be expected of a system using present-day vacuum tubes and crystals? A few assumptions will serve to indicate the problem. If a typical computer has 5,000 cathodes and 10,000 crystals, suppose the tubes will last on an average of 5,000 hours, and the crystals, 10,000 hours. Every 30 minutes one of these aging components may cause a failure. Furthermore, some of these failures will not be steady but will cause marginal operation and thus be very difficult to locate. In a typical 8-hour day this may cause 16 shutdowns. Even if a trouble-location technique is well developed, so that the period of shutdown is short, the efficiency of the machine will be very low. One might ask if a periodic replacement program could be followed which would eliminate many of these component failures. Unfortunately, early failure in groups of new tubes is quite high, so that wholesale replacement on simply a time basis would increase the failure rate.

B. Features of Marginal Checking

The preventive maintenance techniques called marginal checking use performance margins to establish life expectancy of components, so that those with low margins can be removed during a testing period.

Three features of this marginal checking scheme make it very practical for use in large electronic systems:

(1) The checking system can detect imminent failures before they become real failures and cause computational error.

(2) This detection can isolate the failing component to a specific tube, crystal, or resistor.

(3) Such isolation can be so rapid that it consumes only a small percentage of total machine time.

1. Conversion to Real Failures: The conversion of imminent failures to real failures during test periods is the important key in this marginal checking system. Such checking is possible in computers and also in many other pulse systems due to the on-off nature of the circuitry used.

In a computer, information passes from one place to another as the presence or absence of a pulse on a transmission line. It is not necessary that the pulse be of any particular amplitude to get this information to its destination but only that the pulse be large enough to affect the detector. If the presence of a pulse means a 1 and the absence a 0, then a pulse which is too small to affect the detector has the same effect as no pulse at all and so a 0 is recorded.

a. A Simple Computer Channel

Fig. 1 gives a typical basic block diagram often encountered in pulse systems. Gate tube *A*, when open, allows pulses to pass along a channel to a flip-flop. If the pulses are large enough and the flip-flop in proper condition, each pulse will cause a reversal of the flip-flop from a 1 to 0 or vice versa.

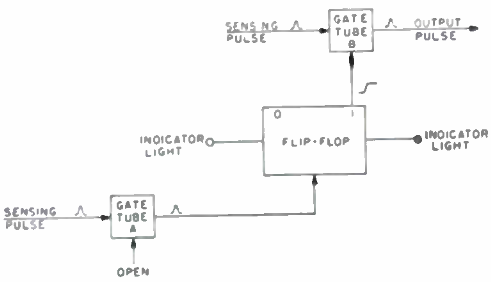

Fig. 1—A typical computer channel.

Two sorts of trouble may develop. First, the gate tube may deteriorate and cause the pulse amplitude to be reduced to a point where the flip-flop will not switch or, second, the flip-flop may refuse to switch because one of its components has deteriorated.

b. Checking the Gate Circuit

The margin of performance in the gate tube (*A*) can be checked by lowering the voltage on the screen of the tube by inserting a negative voltage in series with the screen lead as shown in Fig. 2 (a schematic for gate tube circuit). The pulses emerging from the tube will be lower than they were before the deviation.

If both the flip-flop and gate as shown in Fig. 1 have adequate margins then this marginal checking of the gate circuit will make no difference. This can be detected by another gate tube (*B*) which opens and closes according to the action of the flip-flop. If a sensing pulse is applied to gate tube *B* in Fig. 1, it will pass through to indicate that the flip-flop has switched and opened the channel. In the diagram shown this should occur for every other pulse passing through gate tube *A*.

A low margin in gate tube *A* will interrupt this sequence and no check pulse will emerge from gate tube

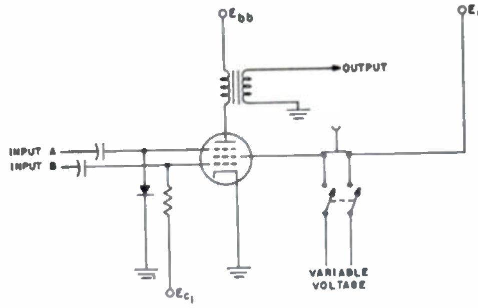

Fig. 2—Marginal checking of gate circuit.

B. From such a test it can be determined whether or not the gate circuit is nearing an unsafe condition. The circuit shown in Fig. 2 has a nominal screen voltage of 90 volts. A typical margin would be minus 20 volts from this value.

c. Checking the Flip-Flop

This first check assumed that the flip-flop was performing normally and acting as a detector for the arrival of pulses. To check this assumption the following test can be made on the flip-flop circuit.

Fig. 3 is a simplified schematic of a flip-flop. One tube must have the ability, when conducting, to hold the other tube in a nonconducting state. The circuit is completely symmetrical. Tube deterioration shows up as a reduction in plate current in one tube with a consequent reduction of bias available to the opposite tube. The large cathode resistor allows considerable aging before the condition becomes intolerable but eventually tube deterioration will become so extreme that instability will occur and the flip-flop will favor one side. Then, whenever it is ordered to change sides by an incoming pulse the circuit will either fail to switch or fail to hold its new position after switching takes place.

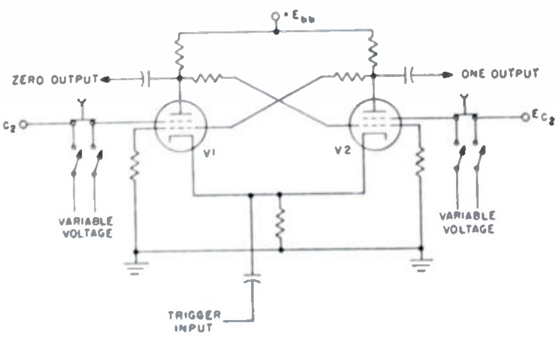

Fig. 3—Marginal checking of flip-flop circuit.

This unfavorable condition can be detected before it leads to failure by feeding the two screen circuits of the flip-flop separately, as shown in Fig. 3, and selectively raising the screen voltage of the normally off tube about 30 volts (nominal value 120 volts). Raising its screen voltage also raises its number 1 grid cutoff voltage. The normally on tube must have a safe margin of plate current available if it is able to hold the tube being checked off under these extreme conditions. If the on tube is weak it will fail to hold off the opposite tube and a spurious switching operation will result. The detection of this condition can be automatic by using the sensing pulses and gate circuits shown in Fig. 1.

d. Testing Crystals in a Clamp Circuit

A third type of conversion which will pick up aging crystals is of considerable interest. Fig. 4 shows a clamping circuit which couples the plate of a flip-flop to a gate tube. Proper operation of this circuit depends on the back resistance of the crystal staying at a high value so that proper clamping action will be available during the period between the voltage pedestals used for clamping. If the crystal deteriorates, the voltage at the grid of the gate circuit will appear as shown at the right of the diagram. Serious deterioration will result in the opening of the gate circuit when it should be closed.

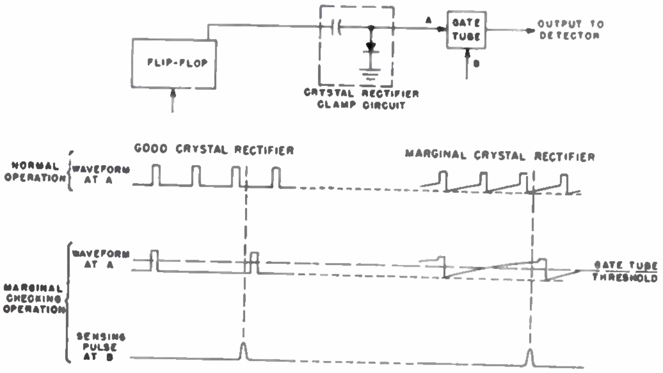

Fig. 4—Marginal checking of clamp crystal rectifiers.

To convert this imminent failure to a real one, a change in the timing of the clamping period is used. A good crystal will operate when a much longer period is allowed, but a deteriorating unit will not hold the bias that long and a failure will result. Values of 16 microseconds and 64 microseconds have been used effectively in this circuit. If a sensing pulse to the gate tube under control of this clamp circuit is inserted near the end of this longer wait period it will be rejected by a good crystal and passed by a deteriorating one. This scheme can then be automatized.

2. *Localizing Failures:* Once an imminent failure has been converted to a real failure by any one of the methods noted above, the problem of detecting the fault and localizing it to a particular source can be very time-consuming if it is not approached in an orderly manner. Fault isolation can be solved if the computer is divided for marginal checking into small logical sections. To simplify the trouble-location scheme, sections should be chosen so that at a given time only one fault can exist.

The logical design of a computer separates it into many channels, all starting at the pulse source and dispersing throughout the system to a destination.

Fig. 5 shows two of these typical channels separated into four sections. The vertical lines indicate how these channels may be broken for purposes of marginal checking and isolation of faults. In each case a pulse starts from the distributor along its channel and arrives at its destination with enough energy to change the condition of a flip-flop circuit in the destination section. If

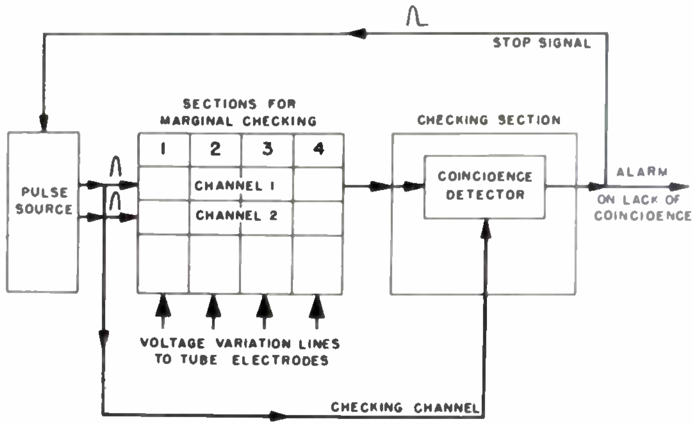

Fig. 5—Computer marginal checking.

each section is subjected to voltage variation and the sequence still functions, the channel can be said to have adequate margins.

The addition of a checking section to these channels allows the checking routine to be carried out automatically by the computer. An error-sensing pulse checks that the information arriving at the checking section via the channel under test is the same as that arriving by a separate checking channel. If the two pieces of information disagree, an alarm is sounded and immediately the pulse distributor is stopped.

Knowing the stopping point of the distributor, the channel at fault is isolated. In addition, knowledge of the section under voltage variation isolates the tube in the channel. The operator can usually find such troubles in a few minutes during such a test routine.

These channels are not used simultaneously but in a time sequence so tubes of the same type, but in different channels, may be grouped in the same section for voltage variation and no loss in isolation results.

3. *Automatic Marginal Checking:* The whole sequence of sending pulses through each of the channels has been automatized in the Whirlwind Computer system sponsored by the Office of Naval Research, at the Massachusetts Institute of Technology.[1] Some 200 sections are used. The computer program sends the pulses through each of the channels in a fraction of a second. Successive sections are selected by telephone switching apparatus and subjected to voltage variation at 5-second intervals. In this way the whole system can be completely checked in about 15 minutes.

[1] The Whirlwind Computer is an electronic digital machine capable of performing at very high speed; i.e., 13,000 multiplications per second.

At present it appears that establishment of adequate margins once each day will be an excellent guarantee that the next 24-hour period will be completely free from error.

It is evident that the basic principles of marginal checking discussed in this paper are simple; but the system must be carefully designed to reap advantages of the checking in an economical way. Too many checking circuits complicate the equipment; not enough will fail to give unique indications and will not isolate defective components.

III. Conclusion

The most significant information about marginal checking is its performance record. Over a period of eight months, a 5-binary-digit prototype arithmetic element at MIT has been running a test problem over and over 24 hours a day. This test system contains about 400 vacuum tubes and 1,000 crystals, and marginal checking is done manually for a period of $\frac{1}{2}$ hour a day and deteriorating components are removed. This equipment has made several runs of three weeks without computational error which represents 2.5×10^{10} correct solutions of the problem, and about 10^{13} correct flip-flop reversals in 25 flip-flop circuits. The average run without error has been eleven days, which represents approximately a 50-to-1 improvement in the results obtained before marginal checking was installed. A run of forty-five days without error was made in early 1950. During this forty-five-day period, 12 tubes, 7 crystals, and 4 resistors were located during marginal checking periods and replaced because of low margins.

When one begins to work with larger systems, there is reason to believe that, with marginal checking, errors will not increase in proportion to the extra equipment involved. A high percentage of the remaining errors are caused by power failure, lightning, and external disturbances independent of the number of vacuum tubes in the system.

A measure of the success of marginal checking in improving the performance of the Whirlwind Computer is shown in Table I.

At present, 3,900 tubes and 11,000 crystals have been running for about 3,300 hours. 32 registers of test storage, made up of toggle switches and flip-flops, allow the solution of several problems which thoroughly test the computer.

TABLE I

Tube and Crystal Failures*

	Tubes	Crystals
Number in use	3,900	11,000
Total failures	187	272
Obvious faults	76	7
Deterioration of operating characteristics	111	265
Failures located by marginal checking	109	223

* Note—Majority of tubes and crystals were in operation for 3,300 hours.

During these installation tests, 187 tubes have been removed, 109 of which have been located by marginal-checking techniques. The majority of tube failures with deteriorating characteristics have been due to the formation of an apparent resistance on the cathode sleeve or in the cathode coating. This defect has been called interface resistance.

Obvious tube faults have been due to gas, broken pins, internal short circuits, and open welds. Many of these have been located by the built-in checking system of the computer without the aid of marginal checking.

Of the 272 crystal failures, 223 were located by the marginal-checking technique. The most serious fault has been a drifting of back resistance to a lower value by a factor of 2 to 10 with the continued application of voltage. The cause of this is not well understood but 1 to 10 per cent of new crystals exhibit this tendency after voltage has been applied for a period of 30 to 60 seconds. A few obvious faults have been due to completely open or short-circuited crystals.

About a dozen tubes and a few crystals have been intermittent. The on-off intermittent is the most difficult fault to locate in electronic circuits. Marginal checking does not aid in isolating this type of failure and this represents one limitation in the system. Complete failure such as filament burnout also cannot be predicted. However, in 3,300 hours of operation, only two tubes have exhibited such failure.

Some of the by-products of marginal checking have proved invaluable in testing the Whirlwind system. Many low performance margins have been found which were due to design weaknesses and not to deteriorating components.

Refinements have been made in the design to reduce noise level and improve timing of pulse sequences and frequency response. These improvements have all been possible earlier in the program than usual, due in a large measure to marginal checking.

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A Digital Electronic Correlator*

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Summary—The relation between correlation functions and the general theory of communication is presented, and this relation leads to a technique for electronic computation of correlation functions and to the design of a machine for carrying out the computation. Because of the requirements of great accuracy and long storage, the machine makes use of binary digital techniques for storage, multiplication, and integration. Descriptions of the more unusual circuits in the machine are given, and circuit diagrams are included. A number of experimental results obtained by the machine are presented.

THE APPLICATION of statistical methods to communication problems is still only a few years old, but already the power of the statistical approach is becoming generally appreciated.[1-5] An adequate body of statistical data is not yet available, however, and this lack prevents the full strength of the statistical technique from being brought to bear on a large number of communications problems. The branch of statistical theory which is applicable here, and which, indeed, must be considerably extended if it is to be of greatest use, is the theory of random processes. The theory of random processes enters because communication equipment must operate for an ensemble of possible signals, none of which can be specified in advance, but which instead are characterized by a set of probability distribution functions. The fundamental statistical parameters which are required for the solution of general communication problems are accordingly the set of functions which characterize the ensemble, namely, the probability distributions

$$P_n(y_1, t_1; y_2, t_2; \cdots; y_n, t_n), \quad n = 1, 2, \cdots$$

where $P_n dy_1 dy_2 \cdots dy_n$ is the probability that a member of the ensemble has values in the ranges (y_1, y_1+dy_1), (y_2, y_2+dy_2), $\cdots$, (y_n, y_n+dy_n) at times $t_1, t_2, \cdots, t_n$. Since P_i can be found from P_j for $j>i$, it follows that the P_n describe the process in successively greater detail as n increases.[6] In applications of the theory it is usual to assume that the probability distributions are invariant under a shift of the origin of time, i.e., that the process is stationary.

Although a knowledge of all the probability distributions P_n is required in order to treat more general communication problems, many problems can be handled through the use of the second probability distribution $P_2(y_1, t_1; y_2, t_2)$. Since for stationary ensembles the distribution P_2 depends not on the absolute values of t_1 and t_2 but on the difference t_2-t_1, it is convenient to abbreviate $P_2(y_1, t_1, y_2, t_2)$ as $P(y_1, y_2; \tau)$ where $\tau=t_2-t_1$. The experimental evaluation of $P(y_1, y_2; \tau)$ for even a single stationary ensemble is a lengthy task,[7] because it requires the evaluation of P for each point in the three-dimensional space y_1, y_2, τ. It is therefore fortunate and of considerable engineering interest that a certain class of communication problems[8] can be treated in terms of the moment of the distribution P

$$M(\tau) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} y_1 y_2 P(y_1, y_2; \tau) dy_1 dy_2. \tag{1}$$

The three-dimensional probability distribution undergoes a smoothing due to the process of integration, and the result is a one-dimensional rather than a three-dimensional function. Furthermore, the moment $M(\tau)$, which may be regarded as the average value of the product y_1y_2 (for a specified τ), can be evaluated without recourse to the probability distribution P. In fact, if $f(t)$ is a member of the ensemble, the average of products of pairs of values of $f(t)$ which are separated by time τ is the correlation function

$$\phi(\tau) = \lim_{T\to\infty} \frac{1}{2T}\int_{-T}^{T} f(t)f(t+\tau)dt. \tag{2}$$

For a stationary process it follows from the ergodic theorem that $M(\tau)=\phi(\tau)$.

Theory of Computation

Since according to the above results only one member $f(t)$ of the ensemble is required to compute $\phi(\tau)$, a convenient approximate method of evaluating $\phi(\tau)$ experimentally is to average a large number of products of pairs of samples of $f(t)$

$$\phi(\tau) = \frac{1}{N}\sum_{1}^{N} a_n b_n(\tau), \tag{3}$$

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[1] N. Wiener, "The Extrapolation, Interpolation, and Smoothing of Stationary Time Series with Engineering Applications," John Wiley and Sons, Inc., New York, N. Y.; 1949.

[2] Y. W. Lee, Class Notes, Massachusetts Institute of Technology Course 6.563; 1948.

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[4] C. E. Shannon, "A mathematical theory of communication," *Bell Sys. Tech. Jour.*, vol. 27, pp. 379–424, and pp. 623–657; July and October, 1948.

[5] S. O. Rice, "A mathematical analysis of random noise," *Bell Sys. Tech. Jour.*, vols. 23, 24, pp. 282–333 and pp. 46–156; July, 1944, and January, 1945.

[6] H. M. James, N. B. Nichols, and R. S. Phillips, "Theory of Servomechanism," MIT Rad. Lab. Series 25, McGraw-Hill Book Co., New York, N. Y.; 1947.

[7] W. B. Davenport, Jr., "A study of speech probability distributions," MIT Doctor of Science Thesis in Electrical Engineering; June, 1950.

[8] Notably the design of optimum linear systems, footnote references 1 and 2.

where N is a large number and a_n and b_n are samples of $f(t)$ which are separated by the interval τ.

Physically, the above discussion means that the computation may proceed as follows: a sample a_1 of the input time series is obtained and stored; after a time τ has elapsed, a sample b_1 is taken and stored; the two samples a_1 and b_1 are multiplied together; the product is stored, and the samples a_1 and b_1 are discarded. The sampling and multiplying process is carried out repetitively, and each time a product is obtained it is added to the cumulative sum of the products previously obtained. After N such products have been obtained, the sum is recorded and the device storing the products is reset to zero. The sum recorded represents the value of $N\phi(\tau)$ for the value of τ under consideration. Proceeding in this way, as many points on the correlation function may be obtained as desired. The procedure just described is used in the present machine. Although an average might be obtained in a shorter period of time by delaying the entire wave form, such a procedure would require the use of more complex equipment.

General Design Specifications

An earlier experimental correlator[9] at the Research Laboratory of Electronics, Massachusetts Institute of Technology, demonstrated the feasibility of high-speed electronic computation of correlation functions. Results on this earlier correlator pointed out the need for great accuracy in the computing circuits and in the specification of the delay τ, as well as a need for a very large range of possible values of τ. Although the preliminary machine served an exceedingly useful purpose, it was limited in the range of delay available, and hence unable to handle many of the problems susceptible to treatment by correlation functions. The present research was initiated in order to provide the laboratory with a highly flexible, general-purpose correlator; one which would meet the requirements of the numerous applications which had been proposed, and which would take advantage, in its design, of experience gained on the first correlator. The following general design specifications for the present machine were arrived at:

1. Wide-band input circuits (dc to 12 Mc/sec).
2. Wide range of delays (0 sec to 0.1 sec).
3. Minimum increments in τ to be less than 0.1 μsec.
4. Value of τ to be known to within 0.01 μsec.
5. Machine to be completely automatic.
6. Accuracy and long term stability to be as good as possible.

The requirement for great accuracy and stability, and especially for very long storage, strongly indicated the use of digital techniques. The binary system is therefore used for storing, multiplying, and integrating.

[9] T. P. Cheatham, Jr., "The experimental evaluation of correlation functions and their use in the statistical theory of communications," MIT Doctor of Science Thesis in Electrical Engineering; 1949.

By this means, possible sources of error are limited to the sampling circuits and to the circuits for translating the samples into binary numbers. Errors from these sources are first minimized by careful selection and design of the circuits used. Remaining errors are further reduced by a special feedback drift-compensating circuit. Descriptions of the circuit techniques used are given below, and together with the general description of the machine, form the body of the paper.

General Description

A functional block diagram of the correlator is shown in Fig. 1. This is a straightforward translation of (3) into functional components. In order to avoid using a separate number generator for each of the two channels, a selector gate is used to route the A and B box cars

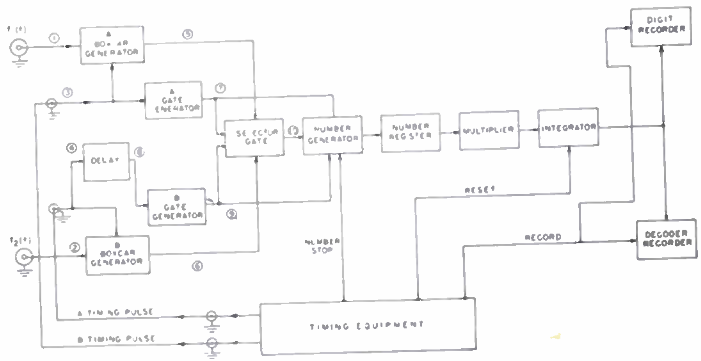

Fig. 1—Functional block diagram of correlator.

(or samples) successively to a single number generator If the inputs $f_1(t)$ and $f_2(t)$ are different, their cross correlation is obtained. If an autocorrelation function is required, the two inputs are connected together. The box-car generators are so called because their outputs consist of wide flat-topped pulses developed from the original narrow samples. Typical wave forms at the numbered points on Fig. 1 are shown in Fig. 2. The value of τ is controlled by fixing the time interval between pulses 3 and 4. Operation of the computer is as follows:

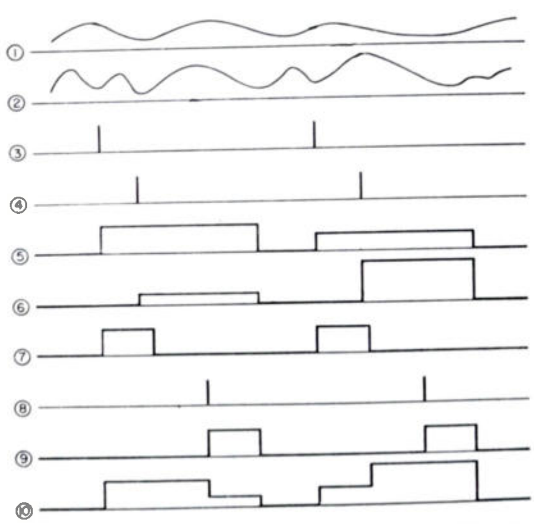

Fig. 2—Wave forms at numbered points of Fig. 1.

Box cars 5 and 6 are obtained from signals 1 and 2 at the time of occurrence of timing pulses 3 and 4. The selector gate normally passes the larger of the two box cars to the number generator, except during occurrence of gate 7 when box car 5 is passed, and during occurrence of gate 9 when box car 6 is passed. Gates 7 and 9 are also fed to the number generator, and during their occurrence the output of the selector gate is coded into binary form. The purpose of delaying pulse 4 to produce pulse 8 is to insure that gates 7 and 9 do not overlap for small or zero values of τ. Thus the number generator has time to code the first box car, gate the resulting binary digits into storage in the number register, and reset itself before it receives the signal (gate 9) to code the second box car. After the A and B numbers are stored in the number register, they are multiplied together in the multiplier and added to the previously accumulated products in the integrator. When a predetermined number of products (of the order of 10^5) has been accumulated, a number stop gating pulse of approximately four seconds duration goes out on the number stop line from the timing equipment to the number generator, and stops the gating of the A numbers into storage. By this means the A number section of the register remains reset to zero. The output of the multiplier therefore becomes zero also, and the number accumulated in the integrator is recorded. This is the value of $\phi(\tau)$ for the particular value of τ being used. The integrator is then reset to zero, and the value of τ is changed in the timing equipment by changing the separation of the A and B timing pulses. The operations of recording $\phi(\tau)$, resetting the integrator, and changing τ are completed in about two seconds. When the number stop gating pulse ends, the machine begins the computation of ϕ for the new value of τ.

Circuit Features

We now proceed to a somewhat more detailed discussion of those parts of the machine which are especially important in meeting the design specifications listed above.

Timing Equipment

Fig. 3 is a block diagram of the portion of the timing equipment which is used in obtaining the A and B timing pulses. These timing pulses must be accurately spaced, since it is their separation which defines τ. A 1-Mc crystal oscillator is used as a reference. The output of the oscillator drives a pulse generator which in turn feeds a cascade of bistable multivibrators. A square wave is taken from one of the latter stages in the cascade to govern the repetition rate at which A and B timing pulses are produced, and therefore the rate at which multiplications are carried out. This rate may be as great as approximately 1,000 per second for small values of τ, but must be decreased as the value of τ increases. Normally the rate is set low enough to include the maximum value of τ used in any one correlation function, and is not changed throughout the computation. By means of the pulse generator, a pulse obtained from one edge of the square wave triggers the phantastrons, and these trigger gating pulse generators whose outputs are set to have a duration equal to the steps in τ which are to be used in the problem under consideration. The gate pulse generators turn on the gates during the occurrence of one of a train of pulses obtained from an earlier stage in the divider cascade. This latter pulse train has a repetition period equal to the desired steps in τ. Numbered wave forms are shown in Fig. 4. The steps in τ which are available by this method range from 1 μsec to 2^{10} μsec. Smaller steps in τ are obtainable by making use of the trailing edges of the phantastron

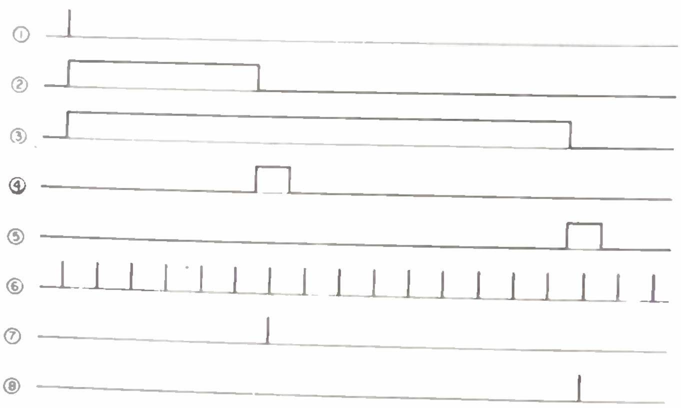

Fig. 4—Wave forms at numbered points of Fig. 3.

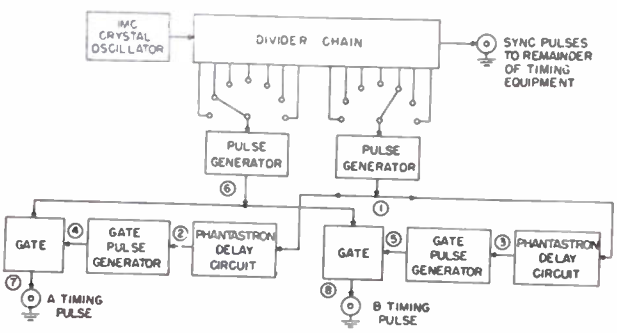

Fig. 3—Block diagram of timing equipment.

outputs directly. By this means, increments in τ as low as 0.02 μsec can be obtained. The phantastron plate catching voltage is under control of a stepping relay which produces 110 different voltages in succession. A particular value of τ corresponds to each position of the stepping relay, and the relay changes after each value of $\phi(\tau)$ is recorded. The maximum range of τ is 110×2^{10} μsec, or about 0.1 sec.

Sampling and Coding Circuits

In order to produce a binary digital representation of the amplitude of the input signal at the time of sampling, the corresponding box car is first converted to a pulse having a duration proportional to the box-car amplitude. The duration-modulated pulse is then used to gate a train of timing pips to a binary counter. The counter is reset to zero prior to the occurrence of each duration-modulated pulse, so that the condition of the counter at the end of the duration-modulated pulse is a binary representation of the box-car amplitude.[10] It is evident that the only important errors produced by the correlator must lie in these circuits, that is, in the box-car generator and in the duration-modulated pulse generator. The duration-modulated pulse is obtained by intersecting the box car with a saw-tooth wave form, and marking the instant of equality of the two voltages. Thus the critical portions of the duration-modulated pulse generator are the saw-tooth wave-form generator and the comparison circuit used to indicate equality between the saw-tooth and the box car. The box-car generators, saw-tooth generator, and comparison circuit are therefore discussed next. A block diagram showing the interconnection of these circuits is given in Fig. 5. The operation indicated by the diagram can be followed with the aid of Fig. 6, which shows wave forms for numbered points on the diagram.

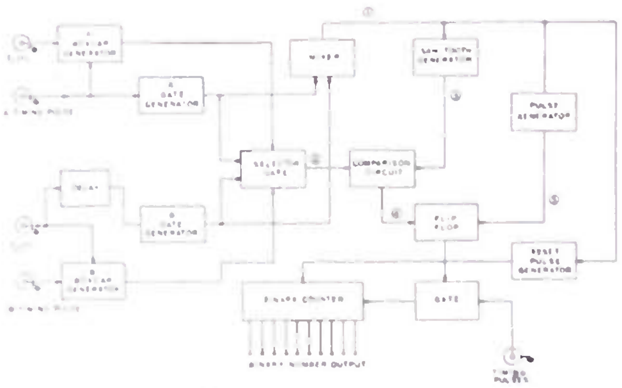

Fig. 5—Block diagram of number generator and associated circuits.

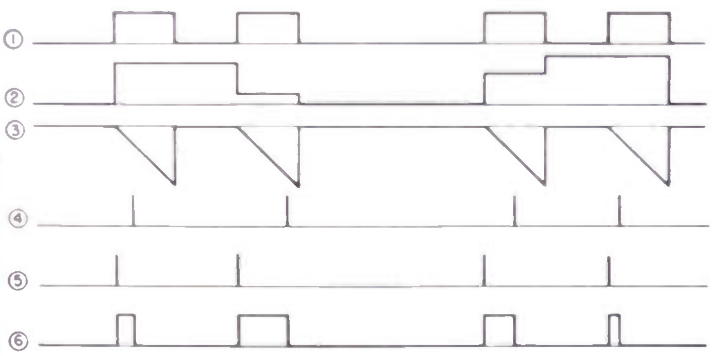

Fig. 6—Wave forms at numbered points of Fig. 5.

Box-Car Generator

A block diagram of one of the box-car generators is shown in Fig. 7. There are two of these circuits, one for each channel. The input timing pulse is reshaped for uniformity in a blocking pulse generator, which produces a very sharp sampling pulse a little less than 0.1 μsec. in duration. The sampling pulse is applied to the suppressor grid of a 6AS6 gate tube normally biassed

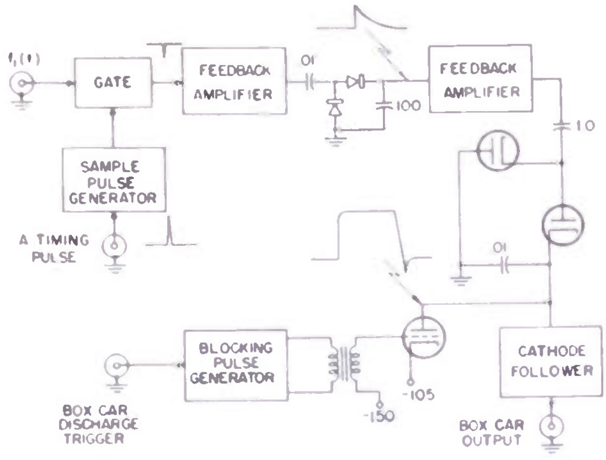

Fig. 7—Block diagram of box-car generator.

below plate current cutoff, and the input time series is applied to the control grid. The need for a very narrow sampling pulse and a wide, flat-topped output pulse imposes conflicting requirements on the box-car generator. The wide output pulse is obtained by storing charge on a condenser. In some cases use is not made of the stored sample until about 600 μsec have passed. In order that the charge not decay appreciably during this interval, a large condenser (0.01 μf) is used. Discharging through a leakage resistance of say 40 megohms, the time constant is 400 milliseconds, and this is satisfactory. Charging through a resistance of 500 ohms, however, which is the order of magnitude that can be easily obtained, the charging time constant is 5 μsec. and a 0.1-μsec pulse is not wide enough. The conflicting requirements are met by widening the original 0.1-μsec sample in successive stages, as shown in Fig. 7.

Saw-Tooth Generator

A schematic diagram of the saw-tooth generator is shown in Fig. 8. This is a Miller feedback circuit using three stages of gain, and gives extremely good linearity. Generation of the saw tooth takes place during the presence of a gating pulse on the normally cut-off suppressor of the first stage of the amplifier. Temperature drift affecting the saw-tooth slope is compensated by returning the resistor of the RC combination which determines the slope to a variable voltage under control of the first or

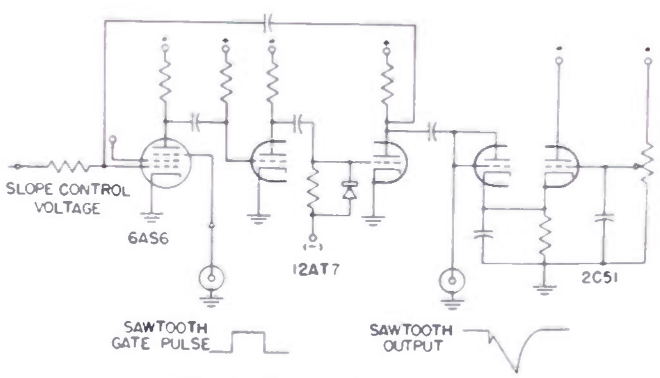

Fig. 8—Saw-tooth generator.

[10] Y. W. Lee, "Experimental Determination of System Functions by the Method of Correlations," Quart. Progress Rep., Res. Lab. of Electronics, MIT, p. 60; January 15, 1950.

principal digit in the B channel of the output of the number generator. The output of the number generator ranges from 0 to 1,023. If the first digit is one, the output is equal to or greater than 512. If the first digit is zero, the output is less than 512. The voltage applied to the slope control resistor is proportional to the relative frequency of occurrence of one in the first digit, and is of the proper polarity to decrease the size of the number if the relative frequency is greater than 50 per cent. Thus the average value of the output of the number generator is held very closely to 512. Use of this drift compensation circuit has reduced errors due to long term drifts in the correlator to negligible importance.

The manner in which the slope control voltage is obtained is shown in Fig. 9. A reset pulse is applied to the flip-flop just before the B number is gated into storage.

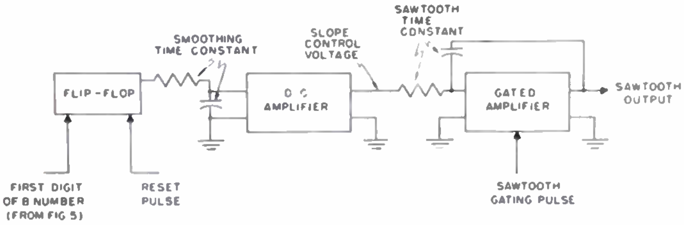

Fig. 9—Drift-compensating circuit.

When the B number is gated into storage, the flip-flop is triggered if the first digit of the B number is one; otherwise the flip-flop remains in the reset condition. The output of the flip-flop is therefore essentially a rectangular wave whose polarity is dependent on the current value of the first digit of the B number. This rectangular wave is smoothed in an RC circuit whose time constant is long compared to the sampling period. The resulting voltage is amplified in the dc amplifier and used to control the slope of the saw-tooth generator.

Comparison Circuit

A schematic diagram of the comparison circuit is shown in Fig. 10. The saw tooth is applied to the grid of V1 and the box-car to the grid of V2. As the saw tooth passes through a narrow range of voltage in the neighborhood of the box-car voltage, the plate current of V1 shifts to V2. No triggering is involved, since no regeneration is present. Because of the pentode V3 in the common cathode circuit of V1 and V2, the plate current of V2 after the shift is equal to the plate current of V1 before the shift. This causes the voltage swings across the plate resistor of V1 and V2 to be equal, and allows fixed grid biasses to be used in V4 and V5. The grids of V4 and V5 are driven in push-pull. A narrow slice is taken near the midpoint of the grid swing, and appears in amplified form at the plate of V4. The resulting essentially rectangular wave form is applied to a regenerative amplifier, or trigger circuit, which derives a sharp pulse from the leading edge of the rectangle. This sharp pulse is used to reset a flip-flop (not shown on Fig. 10, see Fig. 5) previously triggered by the leading edge of the saw-tooth gate. The wave form at the plate of the flip-flop is the required duration-modulated pulse. It is used, as has been indicated, to gate the timing pulse generator which drives the binary counter in the number generator.

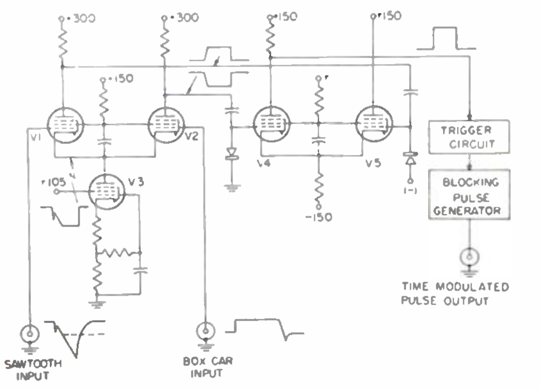

Fig. 10—Comparison circuit.

High-Speed Counter

Very little need be said about the binary counter in the number generator. Since 10 digits are used, a maximum of 1,023 pulses may be counted. In order not to take too long in the counting, a 5-Mc repetition rate is used for the pulses to be counted, thus requiring at most 200 μsec. The first stage of the counter is shown in Fig. 11. The circuit was tested for several weeks at 10 Mc before being incorporated into the equipment. The es-

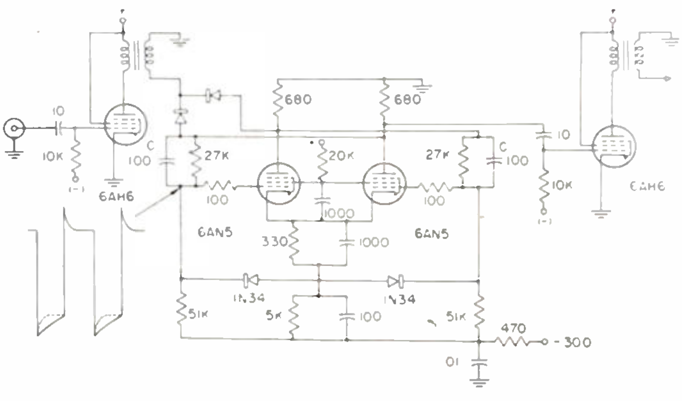

Fig. 11—High-speed counter.

sential feature of the circuit, which allows it to operate ate the unusually high speed, is that crystal diodes from the grids to a tap on the cathode resistor are used to discharge the coupling capacitors C through the low input impedance of the opposite tube. This permits the use of large coupling capacitors (100 $\mu\mu$f in this case) and still permits the coupling capacitors to discharge quickly after each triggering to a voltage from which the flip-flop can again be triggered.

Register and Multiplier

After each of the numbers for the two input channels is generated, it is gated into storage in the number register (see Fig. 12). The register consists of two sets of ten flip-flops each, one set for each of the two numbers to be multiplied, and includes means for shifting the A numbers to the left and the B numbers to the right. Although ten digits are stored in each register, for simplicity only four stages of each are shown in Fig. 12. Assuming that a number is in one of the registers, shifting may be accomplished by applying a shift pulse which rests all of the flip-flops to zero. Associated with each flip-flop is a monostable delay multivibrator. Any flip-flop in state one has its state changed by the reset, and produces a pulse which triggers its associated delay multivibrator. The trailing edge of the delay multivibrator is used to set the next flip-flop to one. Thus each symbol of the stored numbers is moved one stage to the left (in the upper register) or to the right (in the lower register). The shifting operation is made use of during the process of multiplication, in a manner to be described below.

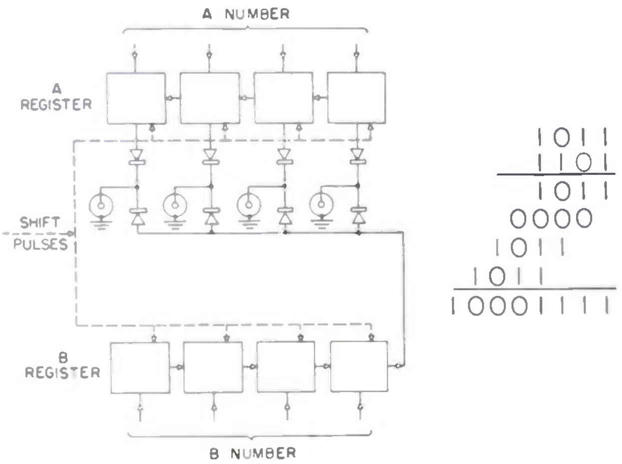

Fig. 12—Block diagram of part of number register.

We first note the numerical example of binary multiplication which is also shown in Fig. 12. The multiplication is carried out in a manner analogous to decimal multiplication, as follows: (1) each digit of the upper number is multiplied by the digit occupying column four of the lower number, and the result is written in the highest empty spaces directly under the upper number; (2) the upper number is shifted one space to the left and the lower number one space to the right; (3) steps (1) and (2) are repeated until all digits have been used; (4) the partial products obtained with each step (1) are summed to give the complete product.

In the machine the process is exactly similar. The value of each partial product is present between shift pulses in the state of the rectifier coincidence circuits shown in Fig. 12. The connection from the register flip-flops to each coincidence circuit is such that if the two corresponding flip-flops are in state one, the output voltage of the coincidence circuit is zero; otherwise it is a large negative voltage. Each coincidence circuit output voltage is used to control the suppressor grid of a 6AS6 gate tube. Application of a positive exploring pulse to the control grid of the gate tube therefore results in a pulse at the gate tube plate only if the two corresponding flip-flops are in state one. The first partial product is present in the state of the coincidence circuits as soon as both numbers are stored. This partial product is read off into the accumulator, or integrator, by applying exploring pulses to the control grids of the gate tubes in time sequence. Trigger pulses occur at the plates of some of the gate tubes and these are used to trigger appropriate stages in the integrator. As soon as all the coincidence circuits have been read, a shift pulse is sent to the register, and the reading process is repeated. This sequence of operations continues until only zeros remain in the register. The shift pulses are then stopped. We observe that the sequence of outputs of a given coincidence circuit corresponds to the numbers in a particular column of the sum of partial products in the numerical example of binary multiplication noted earlier. Hence the output of a given 6AS6 gate tube is always used to trigger the same stage in the integrator. The two ten-digit binary numbers are multiplied together in 250 μsec, once they are both present in the register.

Integrator and Recorder

As has been indicated, the integrator comprises a cascade of scale-of-two circuits, or flip-flops. A multiple pen Esterline-Angus Recorder is connected to the last ten stages of the integrator, and the condition of these stages is read into the recorder at the end of each integration period. The integrator is then reset preliminary to beginning a calculation with the next value of τ. A switch is provided for skipping one or more of the intermediate stages in the integrator, in order that the ten stages recorded may always represent the most significant part of the result. At the same time that the digits are recorded, they are decoded in a voltage adding circuit, and the result is recorded on a General Electric Recording Microammeter. The decoded recording is useful in test runs for immediate observation of results, but is not as accurate as the digit recording.

Sample Results

Fig. 13 shows the correlation function of a sine wave as evaluated and plotted by the machine. The steps in τ are four microseconds.

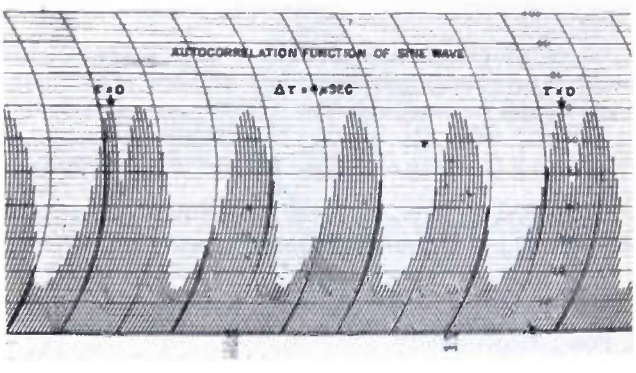

Fig. 13—Autocorrelation of sinusoid.

Fig. 14 shows the correlation function of a limited wave produced by passing wide-band (3 Mc) noise through an RC integrator (5-μsec time constant), and then limiting the output of the integrator to produce a rectangular wave.

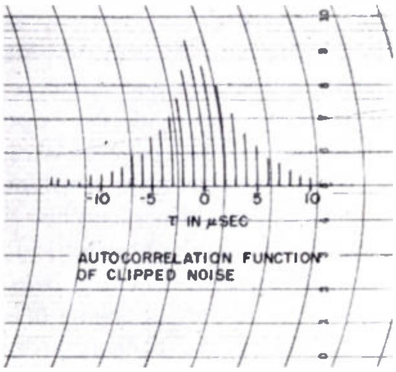

Fig. 14—Autocorrelation of clipped noise.

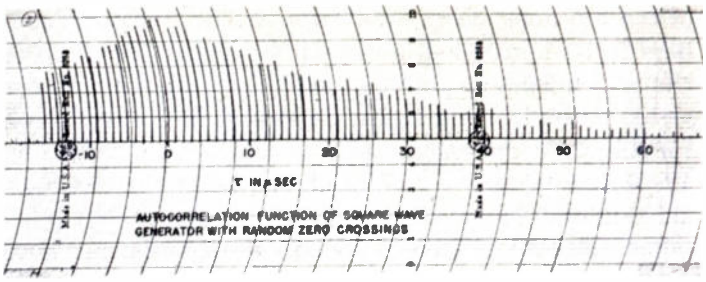

Fig. 15—Autocorrelation of random square wave.

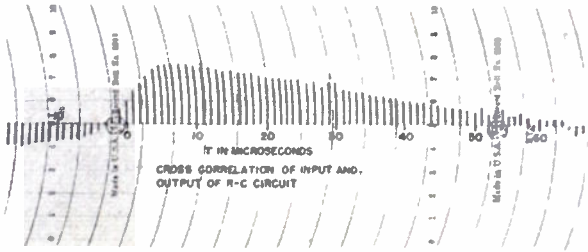

Fig. 16—Convolution of exponentials.

Fig. 15 shows the correlation function of a rectangular wave with independent random zero crossings.[11]

Fig. 16 shows the convolution integral

$$\int_0^\infty e^{-|\tau-\sigma|/T_2} e^{-\sigma/T_1} d\sigma$$

obtained by taking the cross correlation of the output and input of an RC circuit ($T_1 = 50$-μsec time constant). The input circuit was obtained by passing wide-band (3 Mc) noise through an RC ($T_2 = 5$-μsec time constant) integrator.[10]

[11] Obtained from equipment designed by C. A. Stutt.

Acknowledgment

The writer wishes to express appreciation to J. B. Wiesner and Y. W. Lee for the supervision of this project, and to T. P. Cheatham, W. B. Davenport, R. M. Fano, L. G. Kraft, A. J. Lephakis, and C. A. Stutt for their generous assistance on numerous problems connected with the design and testing of the machine.

Some Aspects of Split-Anode Magnetron Operation*

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Summary—Tests of split-anode magnetrons used with butterfly resonators have shown that resonators and tubes at present available are not suitable for use in wide-band butterfly magnetron oscillators, but that such oscillators might have desirable characteristics in some applications if the tubes and resonators were designed for the purpose.

Oscillographic studies appear to indicate that negative slope of portions of the anode current-voltage characteristics can be explained on the basis of back-heating and that negative slope is absent when the current is varied rapidly.

A comparison of various methods of anode-current stabilization showed that smoothest operation is obtained if the magnetic field is produced by an electromagnet excited by the direct anode current.

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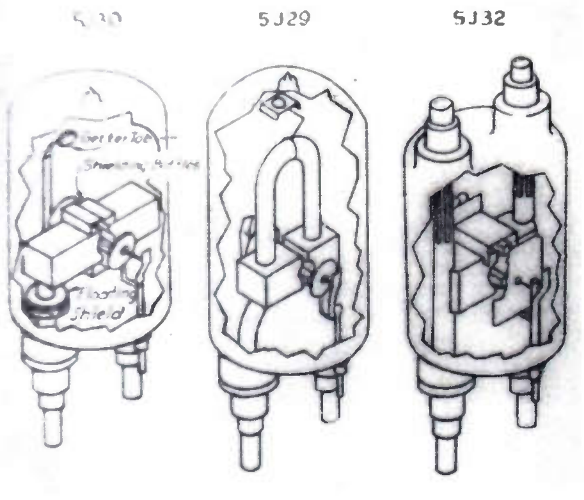
I. Introduction

CONSIDERABLE material is available in the literature on the pulsed operation of cavity magnetrons. The treatment of continuous-wave (cw) operation of split-anode magnetrons, however, is less extensive, and the purpose of this paper is to discuss some of the characteristics of these tubes and their associated circuits.

II. Description of Tubes and Circuits

The magnetrons used were General Electric Company 5J29, 5J30, and 5J32 split-anode magnetrons. The 5J30, shown in Fig. 1(a), has no internal loop and therefore may readily be operated at frequencies as low as a few megacycles per second with an external quarter-wave line. The 5J29, shown in Fig. 1(b), contains an internal loop between the two anode segments. The



(a) (b) (c)

Fig. 1—Split-anode magnetrons.

loop increases the maximum frequency that may be obtained but reduces the tuning range. The double-ended 5J32, shown in Fig. 1(c), was used principally in butterfly-tuned oscillators discussed in Section III. The general form of one oscillator circuit used in this work is shown in Fig. 2(b). Fig. 2(a) shows the manner in which the magnetic field was applied, and Fig. 2(c) the way in which cooling-water connections were made to the anode leads of the tubes.

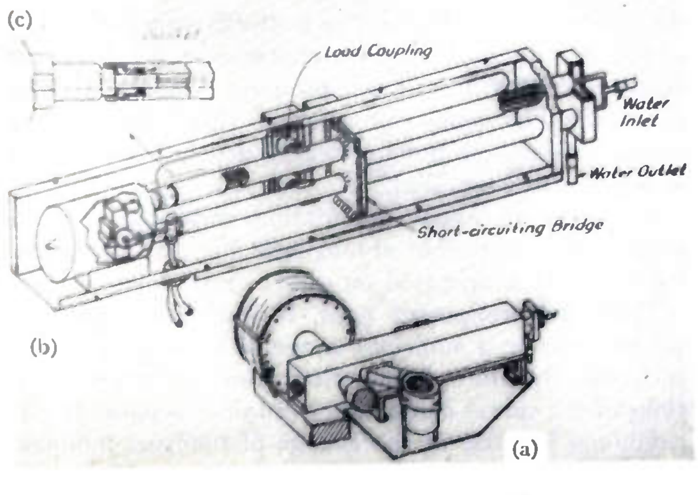


Fig. 2—Magnetron oscillator assembly.

Not only must the anodes of split-anode magnetrons be water-cooled, but the filament leads and the entire envelope must be air-cooled. Uniform cooling of the envelope is important. The internal loop of the 5J29 allows the cooling water to enter through one anode lead and leave through the other. In the 5J30 and 5J32, however, the water must enter both anodes through small concentric tubes contained within the tubular lines and leave through the lines, as shown in Fig. 2. The inner tubes must extend into the anodes in order to provide proper cooling.

III. Butterfly-Tuned Oscillators

If the standard type of butterfly tuner could be adapted to serve as a resonator for a split-anode magnetron, several advantages over parallel-line oscillators could be achieved: (1) the physical size of the oscillators could be greatly reduced; (2) the tuning mechanism would be much simpler; (3) the position of the load-coupling point could be made independent of tuning; and (4) the tendency toward resonance-mode jumping would be greatly reduced.

The materials available for the construction of such an oscillator are not what might be desired. First, the butterfly tuners available are all low-power receiver units whose voltage ratings are far below the magnetron requirements. Second, the magnetrons available have all been built for use in parallel-line systems and thus are not ideally suited for connection to the butterfly tuner. The primary difficulty turns out to be the length of line between the electrodes and the butterfly. The butterfly tends to act as a capacitive short circuit on a short section of line made up mainly of the tube leads. The frequency range is therefore much smaller than that of the butterfly resonator itself.

Several oscillators working on this principle were built and fair operational results were obtained. One of the butterfly tuners used is shown in Fig. 3. The load was coupled, in general, directly to the short section of parallel line connecting the tube and the tuner.

Arcing inside the tuner due to insufficient spacing was a frequent occurrence. In an endeavor to increase

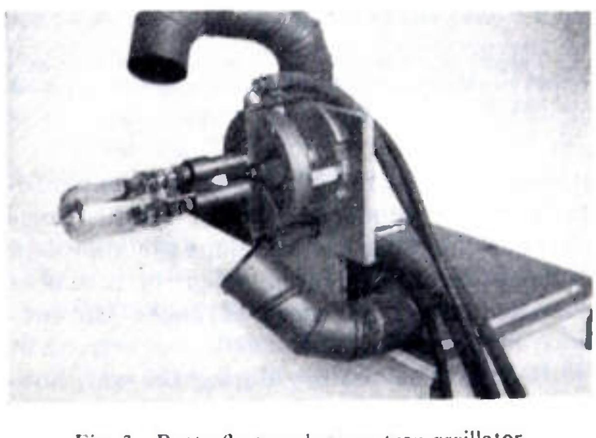


Fig. 3—Butterfly-tuned magnetron oscillator.

the spacing of available types, some units were dismantled and reassembled with different stacking arrangements. As might have been predicted, these units were not ideal resonators, having many spurious modes. One of the oscillators built, which used a 5J30 tube, had a frequency range from 127 to 385 Mc and a maximum power output of approximately 500 watts at 385 Mc.

The butterfly tuner could be more successfully used in conjunction with split-anode magnetrons if the current types of butterfly tuners and magnetrons were modified for the purpose. A tube could be built with much shorter leads and the butterfly spacing might be changed. Since small size is desirable, however, the ideal solution might well be to include the butterfly tuner within the magnetron envelope. The disadvantage of such a structure would be the increased complexity of tuning

IV. Amplitude-Modulation Characteristics

Fig. 4 shows typical characteristics of average anode voltage versus average anode current for a split-anode magnetron at fixed magnetic flux density and several values of filament current. These characteristics were obtained with the magnetron oscillating, but each point on the curves was taken with fixed values of direct anode current and voltage. Characteristics obtained in this manner will be termed "static current-voltage characteristics," in contrast with characteristics obtained with periodically varying average current and voltage, which will be termed "dynamic current-voltage characteristics."

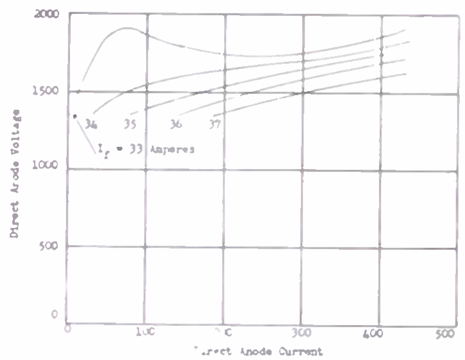


Fig. 4—Typical characteristics of average anode voltage versus average anode current for a split-anode magnetron at fixed magnetic flux density.

An interesting feature of the characteristics of Fig. 4 is the negative slope observed in certain ranges of filament current. This negative slope would be expected to result in unstable operation when the tube is amplitude-modulated by variation of anode current. Experience in the use of split-anode magnetrons at the Radio Research Laboratory during the war, however, showed that stable amplitude modulation could be obtained. These facts suggest that the static current-voltage characteristics do not hold under dynamic conditions, and led to the oscillographic determination of dynamic characteristics.

The circuit used in the determination of dynamic characteristics is shown in Fig. 5. By means of this

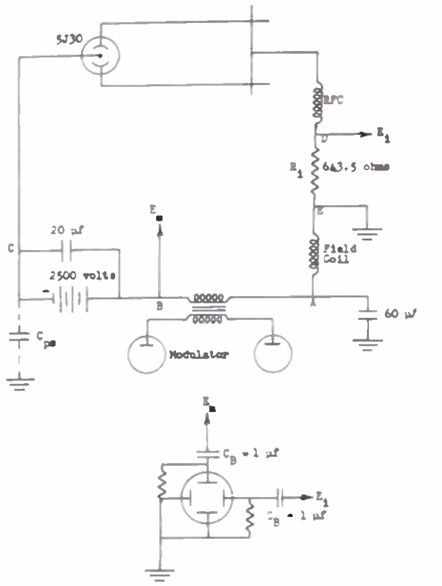


Fig. 5—Circuit used in the determination of the dynamic characteristics of split-anode magnetrons.

circuit the current could be varied periodically about an operating value at any frequency within the range from 500 cps to 5,000 cps. The voltage across the resistor R_i, which is proportional to the instantaneous magnetron current, was impressed across the x-deflection plates of an oscillograph tube, and the applied modulation voltage was applied across the y-deflection plates. The instantaneous anode voltage was found by subtracting the instantaneous voltage across R_i from the instantaneous applied voltage, i.e., subtracting the x-deflection from the y-deflection. In this manner dynamic curves of alternating anode voltage versus alternating anode current were obtained.

In the study of dynamic characteristics, most of the data were obtained with the butterfly-tuned oscillator of Fig. 3 because of its compactness, ease of tuning, and relative freedom from mode jumping. Comparison with a parallel-line resonator showed that the dynamic characteristics are not noticeably dependent upon the type of resonator used.

In order to avoid modulation resulting from an alternating component of magnetic flux, the magnetron filaments were operated on direct current.

With the equipment used, it was not possible to modulate over a sufficient range of current to obtain the entire dynamic characteristics, and the various portions of the curves could not be obtained separately and combined because of the change of filament temperature with average anode current as the result of back-heating. For the limited current swings obtainable, however, the dynamic curves, unlike the static curves, always show a positive slope and show little or no curvature. Because of the small curvature, the slope of the dynamic curves at various operating points may be assumed to be equal to the ratio of the rms value of the alternating component of anode voltage to the rms value of the alternating component of plate current. The curves of Fig. 6, showing rms anode current versus

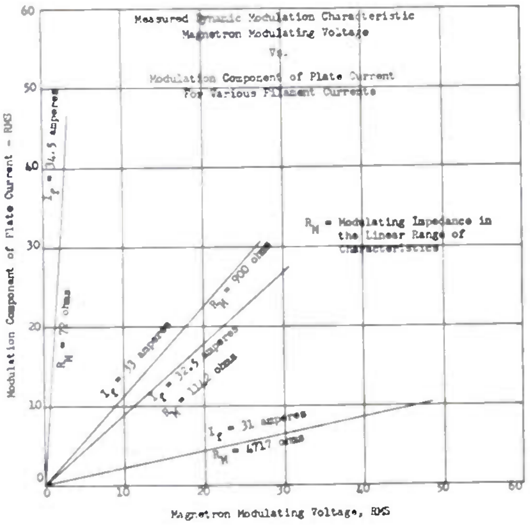


Fig. 6—Dynamic modulation characteristics of a split-anode magnetron for four values of filament current.

rms anode voltage at four values of filament current, indicate that this assumption is justified over a limited range of operation, and it is therefore unnecessary to use oscilloscopic techniques except to check the linearity. Curves of detected output versus modulating voltage were essentially linear. Although the entire dynamic characteristics could not be obtained experimentally, the decrease in slope of the dynamic characteristics with increase of filament temperature at both constant anode current and constant anode voltage indicates that the complete family of dynamic characteristics is of the general form shown in Fig. 7.

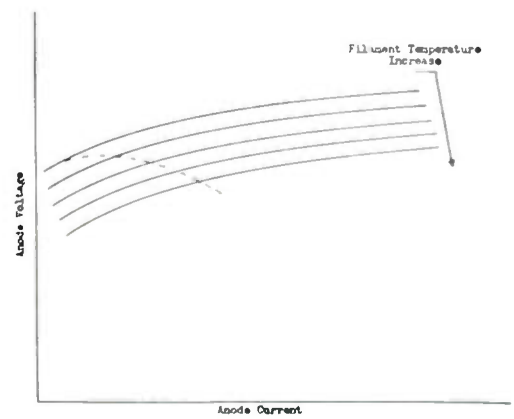


Fig. 7—Static characteristic curve predicted from dynamic characteristics.

The difference between static and dynamic characteristics can be explained on the basis of back-heating. Under dynamic conditions the average anode current remains constant throughout the cycle and therefore back-heating and filament temperature remain constant. The static characteristics, on the other hand, are obtained by varying the average anode current at constant filament current. As the average anode current is increased, increased back-heating raises the filament temperature. (The increase in temperature is clearly visible in these tubes.) Since the exact form of the dynamic characteristics and the manner in which filament temperature depends upon anode current are not known, the shape of a static characteristic cannot be predicted exactly from a family of dynamic characteristics. The assumption that filament temperature increases with anode current because of back-heating under static conditions results in a predicted static characteristic of the general form of the dashed curve in Fig. 7. Whether the slope of any portion of the predicted curve is negative or positive depends upon the slope and spacing of the constant-filament-temperature (dynamic) curves and upon the manner in which filament temperature varies with average anode current, but the theory shows that the static characteristics might be expected to have negative slope in at least a portion of the operating region. It also suggests that negative slope, which may result in unstable operation (see Section V), could be prevented if the effect of back-heating upon filament temperature could be made small in comparison with the effect of filament heating current. This is probably the explanation of the fact that only the 33-ampere curve of Fig. 4 shows negative slope.

The marked differences between the static and dynamic characteristics of split-anode magnetrons indicated clearly that the modulation resistance of these tubes in amplitude modulation cannot be determined from static current-voltage characteristics. The modulation resistance may be readily determined, however, from measured values of modulation-frequency anode current and voltage in a circuit of the form of Fig. 5.

V. Limitation of Anode Current

The 33-ampere curve of Fig. 4 shows that if the anode voltage is gradually raised, the anode current will increase in a stable manner until the voltage reaches the value corresponding to the peak in the curve. Beyond this value of voltage, however, the voltage required across the tube decreases as the anode current increases, and therefore, if the voltage supply has good regulation and the anode-circuit resistance is low, the current will rise abruptly to a value of 400 to 500 ma. Under some operating conditions the anode current may suddenly rise to values that are sufficiently high to cause damage or destruction of the tube. Abrupt changes in current are obviously objectionable in the amplitude modulation of the tube.

The simplest method of stabilizing the circuit against abrupt increases of current is to use resistance in series with the anode. The manner in which stabilization occurs can be readily seen by the use of a "load line" in the current-voltage diagram, in a manner analogous to that used in the analysis of amplifier tubes. Through a point of the voltage axis corresponding to the anode supply voltage, a line is drawn with negative slope equal in magnitude to the anode circuit resistance, as shown in Fig. 8. If the resistance is high enough so that the magnitude of the slope of this load line exceeds the highest magnitude of the negative slope of the tube characteristic, only one intersection is obtained. There can then be only one stable value of current, and an abrupt increase of anode current at constant anode supply voltage cannot occur. The objection to this solution of the problem lies in the power loss in the series resistance.

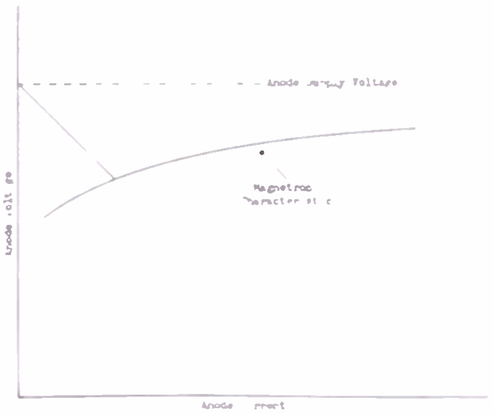


Fig. 8—Limitation of anode current by series resistance.

A more common method of stabilization is the use of a power pentode, or of a parallel combination of two or more pentodes, in series with the magnetron cathode. In the operating range of power pentodes the plate current varies comparatively little with plate voltage, but is determined principally by the control-grid voltage.

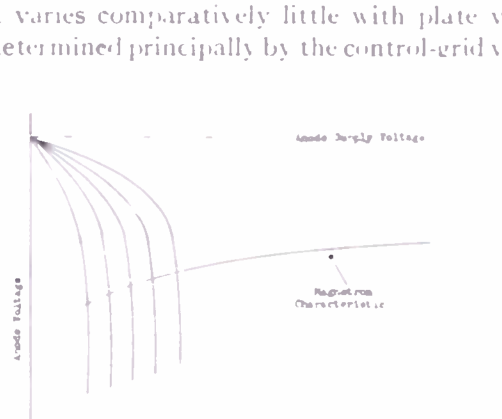


Fig. 9—Limitation of anode current by series pentodes.

The anode diagram of Fig. 9, in which the load line of Fig. 8 is replaced by the family of pentode plate characteristics (pentode plate voltages are indicated as a voltage drop relative to the supply voltage), shows the manner in which stabilization is obtained. In addition to the lower power loss and lower plate supply voltage required, the pentode method of stabilization has the advantage that current modulation of the magnetron can be produced by applying a relatively small modulating voltage to the pentode grids.

A third method of stabilization is the use of a circuit in which the filament current is automatically reduced as the anode current increases. The objection to this method of stabilization is the thermal inertia of the filament and increased low-frequency pulsing.

A fourth method of stabilization consists of the use of an electromagnet, excited by the anode current, to provide the magnetic flux for the magnetron. Fig. 10 illustrates the mechanism of stabilization. Increase of

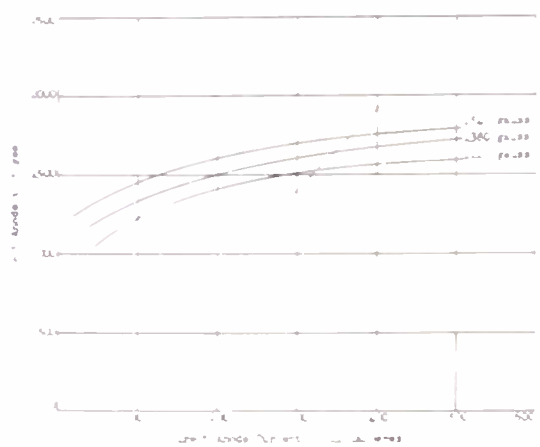


Fig. 10—Limitation of anode current by means of an electromagnet excited by the magnetron anode current.

anode current is accompanied by a proportional increase of flux density. The static path of operation is therefore of the form shown by the dashed curve. The slope of the static characteristic is effectively increased and negative slope is avoided. This method of stabilization has been used previously on cavity magnetrons.

VI. Series Magnet Stabilization

Fig. 11 shows static current-voltage characteristics for a 5J29 tube operated with series field excitation. The four curves correspond to four values of number of turns on the electromagnet. An advantage of the use of this type of stabilization is that oscillation is obtained at much lower values of anode voltage than with constant flux, and that the amplitude of oscillation can be increased smoothly over a wide range by increasing the anode voltage.

The breaks in the characteristics of Fig. 11 for the smaller number of magnet turns indicate pulsing

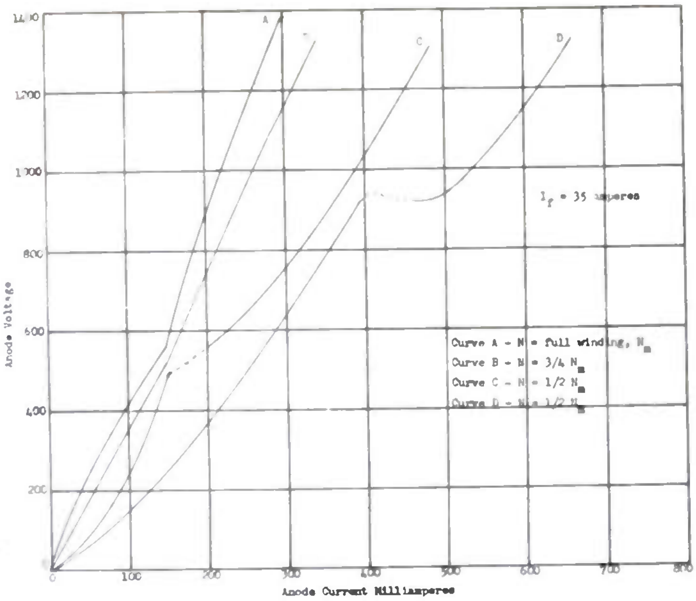


Fig. 11—Static current-voltage characteristic for a split-anode magnetron with series field excitation.

(periodic variation of amplitude), due to improper loading. In general, the tendency toward low-frequency pulsing is very much lower with series-magnet excitation than with permanent-magnet excitation.

It is apparent from Fig. 11 that the steepness of the static characteristics with series excitation increases with the number of turns on the electromagnet. This suggests that operation at essentially constant current should be possible if the rate of change of flux with anode current can be made sufficiently great. This result was accomplished by the circuit of Fig. 12. In this circuit the magnet current is controlled by a number of 304-TH power tubes in parallel, which are in turn controlled, through the 6SK7 amplifier stage, by the voltage drop across the resistor R_1 in the cathode circuit of the magnetron. In this manner the change of magnet current is made much greater than the change of magnetron anode current, and the operating anode current is made essentially independent of operating voltage.

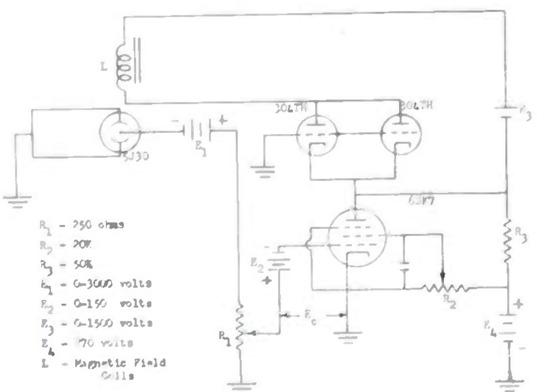


Fig. 12—Circuit for constant-current operation of a split-anode magnetron.

Fig. 13 compares static current-voltage curves for a 5J30 operated with fixed magnetic field, with series-excited magnetic field, with amplifier-controlled magnetic field (circuit of Fig. 12), and with constant magnetic field and series pentodes. Fig. 14 shows corresponding curves of power output versus anode current.

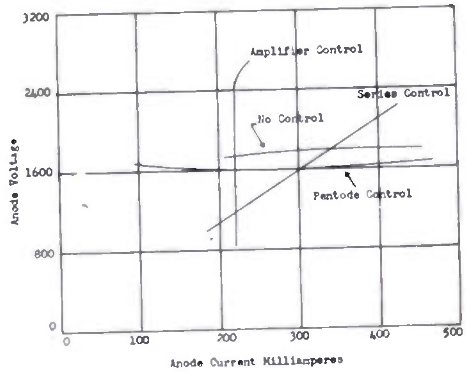


Fig. 13—Comparison of static current-voltage curves for different methods of operation.

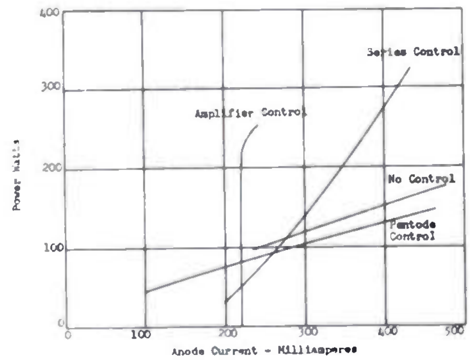


Fig. 14—Curves of power versus current for different methods of operation.

VII. Acknowledgment

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Effects of Space Charge on Frequency Characteristics of Magnetrons*

H. W. WELCH, JR.†, ASSOCIATE, IRE

Summary—**Properties of the magnetron space-charge swarm which affect the propagation of electromagnetic waves are defined in terms of an effective dielectric constant. The space charge is found to be doubly refractive in nature, the velocity of propagation depending on the direction of propagation of the wave, polarization of the wave, and frequency. Effects of synchronism of the rotating space-charge swarm are discussed qualitatively. Experimental results which check parts of the theory are presented. The relationship of the space charge to the circuit is discussed in terms of the nonoscillating and the oscillating magnetron.**

Introduction

THE COMPLETE DISCUSSION of space-charge effects on frequency characteristics of continuous-wave magnetrons requires attention to a varied subject matter. Much of this subject matter has been treated in reports of government agencies and in the journals, and is generally understood. There are, however, several points at which present knowledge becomes inadequate background for an understanding of the mechanism of magnetron operation. This is particularly the case when one is to predict quantitatively the behavior of magnetron space-charge clouds under the influence of radio-frequency fields.

The circuital aspects of magnetron frequency characteristics are generally treated by establishment of an equivalent circuit and interpretation of that equivalent circuit in terms of experimentally measurable quantities. The most conveniently measurable quantities are resonance wavelength, loaded Q, and minimum standing-wave ratio. The relationships between these quantities and other unmeasurable quantities in the equivalent circuit are fairly well defined and understood. This theory can be extended to explain semiquantitatively effects of the output circuit and load on magnetron frequency characteristics such as frequency pulling and long-line effect.

Frequency characteristics of an operating magnetron must be obtained from the following types of experimentally obtained information: Rieke diagrams, relating frequency of oscillation and power output to load characteristics; frequency pushing measurements, relating frequency and plate current for constant loading; and modulation characteristics determined by spectral measurements of various types. Interpretation of these types of data depends on knowledge of the physics of space-charge effects in the oscillating magnetron and, at this point, is almost entirely qualitative.

Another type of data, resulting from measurements made on magnetrons in which electrons are circulating but not reaching the anode, is very useful as an aid to the understanding of space-charge behavior. The method of measurement is the same as that used for cold impedance tests on microwave tubes and resonant cavities. In order to differentiate, the term "hot impedance test" is used, implying that the magnetron is "hot" and capable of drawing plate current if the conditions of anode voltage and magnetic field are proper adjusted.

In order to provide theoretical interpretation of the experimental results, it is necessary to study two types of properties of the space charge. These are the following:

Type 1—Properties having to do with the distribution of angular velocity, field, potential and charge density, and definition of the space-charge boundary in the magnetron interaction space.

Type 2—Properties having to do with the propagation of electromagnetic waves in the space-charge distribution defined by the results of the study of properties of Type 1.

The results of the study of properties of Type 1 will be presented when needed but not derived in this paper. The primary purpose will be the detailed discussion of properties of Type 2 and interpretation of the various effects of space charge on magnetron frequency characteristics. It will be pointed out that these effects result from three more-or-less separate phenomena which may occur together or separately. The picture is still incomplete experimentally, because of very large quantities of data which are necessary to survey the entire range of the variable parameters, and, theoretically, because of the complexity of parts of the necessary mathematical development. Another important factor is that, in most conventional magnetrons, the total effect of space charge on frequency is a shift of less than one or two per cent. A detailed study therefore requires a number of measurements accurate within at least 0.1 per cent.

The need for the study of space-charge effects on frequency characteristics lies in two directions. In the first place, it becomes possible for experimental results to provide a check on the basic theories of the magnetron space charge. In the second place, understanding of the use of the magnetron space charge in electronic frequency control or modulation is increased.

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The various conditions under which data may be taken give a wide range of possibilities for interpretation. In certain cases quantitative agreement between theory and experiment are obtained. The present paper is not meant to be a complete and final analysis of the problem of magnetron space-charge and frequency characteristics. It is intended to relate as many as possible of the known facts and theories in such a way that they can be used as a guide for further research and development. Gaps in both experimental data and theory will be pointed out with the hope that someone will have the necessary information, or the time to acquire the necessary information, to fill them in.

Formation of the Magnetron Space Charge

The static cylindrical magnetron space-charge distribution, which is often called the Hull or Brillouin solution, may be thought of as a swarm of electrons revolving around the cathode. This swarm is characterized by the condition that no radial current exists and by the following angular velocity distribution:

$$\omega = \frac{Be}{2m}\left(1 - \frac{r_c^2}{r^2}\right) \tag{1}$$

where

B = axially directed magnetic field
r_c = cathode radius
r = radius which locates electron
e = absolute value of electronic charge
m = electronic mass.

However, assuming no energy exchange with the surroundings, this distribution of angular velocity must exist in the static magnetron regardless of the radial velocity, initial or otherwise. If no radial velocity is present, then the corresponding potential distribution represents minimum energy of the electrons.

$$Ec = \frac{1}{2} m \left(\frac{Be}{2m}\right)^2 r^2 \left(1 - \frac{r_c^2}{r^2}\right)^2 \tag{2}$$

where

E = electric potential.

If current is passed radially through the cloud, additional energy must be supplied which would add to the potential of the electrons given by (2). If the anode potential E_a is insufficient to supply the minimum energy at the anode (given by substituting the anode radius r_a into (2)), then the swarm of electrons must be bounded between cathode and anode. In order to calculate effects of the space charge under these conditions, the position of this boundary and the space-charge distribution within should be known. The position of the boundary is readily calculated because the potential and field at the swarm boundary are known. If no electrons are crossing the boundary, the potential at the boundary must be given by (2). The field is, therefore,

$$-\frac{\partial E}{\partial r} = \frac{1}{4}\frac{e}{m} B^2 r \left(\frac{r_c^4}{r^4} - 1\right). \tag{3}$$

By Gauss's theorem the total space charge per unit length within a radius r will be

$$\begin{aligned} \tau &= 2\pi r \epsilon_0 \left(-\frac{\partial E}{\partial r}\right) \\ &= \frac{1}{2} \pi\epsilon_0 \frac{e}{m} B^2 r^2 \left(\frac{r_c^4}{r^4} - 1\right) \end{aligned} \tag{4}$$

where

τ = total space charge per unit length
$\epsilon_0 = (1/36\pi) \times 10^{-9}$ farads per meter.

For a cylindrical diode

$$E_a - E = \frac{-\tau}{2\pi\epsilon_0} \log \frac{r_a}{r} \tag{5}$$

where

E_a = the anode potential
E = potential at some point in charge free space r
τ = charge per unit length inside r.

If we let

$r = r_H$ = boundary of space-charge swarm
$E = E_H$ = potential at r_H from (2)
τ = value defined by (4) for $r = r_H$,

and substitute from (2) and (4) into (5), we have

$$E_a = B^2 \frac{e}{8m} r_H^2 \left[2\left(1 - \frac{r_c^4}{r_H^4}\right) \log \frac{r_a}{r_H} + \left(1 - \frac{r_c^2}{r_H^2}\right)^2\right]. \tag{6}$$

This equation shows us that for a given magnetron, if E_a/B^2 is kept constant, the radius of the space-charge swarm remains constant (under static conditions).

It is important to note that in the derivation of (4) and (6) it was unnecessary to specify the distribution of space charge and potential inside the swarm. It is known that a number of solutions for these distributions are possible in which electrons stream back and forth between the cathode and the outer boundary of the space-charge swarm. Corresponding to each of these double-stream or multiple-stream solutions, as they are called, there would be a different potential and space-charge distribution within the swarm. All of these solutions have been obtained for the plane magnetron.[1] However, for the cylindrical magnetron the complete solution is not yet available. If it assumed that the solution is not multiple stream (i.e., that all of the electrons in the swarm are traveling in circles around the cathode), the resulting space-charge distribution is

[1] J. C. Slater, "Microwave Electronics," D. Van Nostrand Co., New York, N. Y., p. 336; 1950.

$$\rho = -\frac{1}{2}\epsilon_0 \frac{e}{m} B^2\left(1 + \frac{r_c^4}{r^4}\right). \qquad (7)$$

This is obtained by applying Poisson's equation to (3), and therefore corresponds to minimum energy in the electrons. This distribution will be used in the following discussion.

Propagation of the Electromagnetic Wave in the Magnetron Space Charge

The radio-frequency properties of the space charge have been analyzed previously in two important articles.[2,3] However, many points of particular interest to the problem of frequency characteristics have not been emphasized. In order to establish the relationship of the following treatment to the two previous treatments, the major differences will be pointed out. All three methods are alike in that the space-charge distribution given by (7) is the starting point, and, as was pointed out in the last section, there is no ambiguity in the use of (6) to determine the boundary of the space-charge swarm.

The fundamental equation of motion of an electron in space, in vector form, is

$$\frac{d\vec{v}}{dt} = -\frac{e}{m}(\vec{F} + \vec{v} \times \vec{B}) \qquad (8)$$

where

$\vec{v}$ = velocity of the electron

$\vec{F}$ = electric field

$\vec{B}$ = magnetic field.

It is assumed that

$$\vec{v} = \vec{v}_0 + \vec{v}_1$$

$$\vec{F} = \vec{F}_0 + \vec{F}_1$$

$$\vec{B} = \vec{B}_0 + \vec{B}_1$$

where $\vec{B}_0$, $\vec{v}_0$, and $\vec{F}_0$ are static values and $\vec{B}_1$, $\vec{v}_1$, and $\vec{F}_1$ are impressed radio-frequency values. Substituting into (8) and keeping the terms involving radio-frequency values, we have

$$\frac{\partial\vec{v}_1}{\partial t} + (\vec{v}_0\cdot\nabla)\vec{v}_1 + (\vec{v}_1\cdot\nabla)\vec{v}_0 + (\vec{v}_1\cdot\nabla)\vec{v}_1$$

$$= -\frac{e}{m}(\vec{F}_1 + \vec{v}_1 \times \vec{B}_0 + \vec{v}_0 \times \vec{B}_1) \qquad (9)$$

where we are following the motion of a particular electron. The left side is the total derivative $d\vec{v}/dt$ under these conditions. It is generally agreed that the term $\vec{v}_0 \times \vec{B}_1$ is negligible compared to other terms. In the paper by Blewett and Ramo the term $\vec{v}_1 \times \vec{B}_0$ is also neglected. Actually the effect of the magnetic field is quite important, as will be shown in the following, and as was also pointed out by Lamb and Phillips.

In the paper by Lamb and Phillips it was assumed that v_1 was a small perturbation and therefore the term $(\vec{v}_1\cdot\nabla)\vec{v}_1$ could be neglected. Their results apply particularly to frequencies near the cyclotron frequency

$$\left(f_c = \frac{1}{2\pi}\frac{Be}{m}\right)$$

and are limited to very small sheaths of electrons surrounding the cathode. Damping is treated in a qualitative sense. Their results will be discussed further at the end of this section.

In the present approach, a simplified problem is treated in order to obtain more generally applicable results. These results will indicate an approximate behavior to be expected in a magnetron which seems to check closely enough with experimental observations to justify the method of treatment. It is assumed that the space-charge swarm is moving with a uniform velocity v_0 so that the term $\vec{v}_1 \cdot \nabla\vec{v}_0$ is dropped in (9). Actually

$$v_0 = \omega r = \frac{Be}{2m} r\left(1 - \frac{r_c^2}{r^2}\right),$$

from (1). Also, the wave is assumed to be propagated perpendicular to $\vec{v}_0$ so that the product $\vec{v}_0 \cdot \nabla\vec{v}_1$ vanishes. The force equation under these conditions becomes simply

$$\frac{\partial\vec{v}_1}{\partial t} = -\frac{e}{m}(\vec{F}_1 + \vec{v}_1 \times \vec{B}) \qquad (10)$$

where the subscripts "1" only serve to indicate radio-frequency values and will be dropped in the remainder of the discussion.

Ordinarily in treatment of electrodynamics of a moving medium the effect of the motion does not become appreciable until the velocity is an appreciable fraction of the velocity of light. In the case of the magnetron, however, the effect of the motion may become important when the angular velocity of the edge of the swarm approaches synchronism with the angular velocity of the radio-frequency wave in the interaction space. Under these conditions the electrons can contribute energy to the radio-frequency wave and begin to slow down and form spokes extending toward the anode. These spokes assume a certain phase relationship to the radio-frequency wave which changes with plate voltage and affects frequency in a way not covered by the treatment in this section. Thus the results of this section should only be considered valid for

$$\omega \ll \omega_n \qquad (11)$$

[2] J. P. Blewett and S. Ramo, "High frequency behavior of a space charge rotating in magnetic field," *Phys. Rev.*, vol. 57, pp. 635–641; April, 1940.

[3] W. E. Lamb, Jr., and M. Phillips, "Space charge frequency dependence of magnetron cavity," *Jour. Appl. Phys.*, vol. 18, pp. 230–238; February, 1947.

where

$\omega_n = 2\pi f/n$ (synchronous angular velocity)

f = frequency of the radio frequency impressed on the magnetron structure

n = mode number = $\frac{1}{2}$ number of anodes in π mode.

Since we are considering the space charge as an atmosphere of determined density and boundary, it is immaterial what system of co-ordinates is used for the force equation. We are considering properties of space-charge atmosphere as they affect propagation, so it will be simpler to treat a plane wave. The results will then be interpreted in the case of the particular geometry of the magnetron. We will assume first a configuration as shown in Fig. 1(a). Magnetic field is oriented in the z direction; a plane wave is propagated in the x direction. Fig. 1(b) shows, in comparison, the actual case in a magnetron. The force equations and Maxwell's equations yield the following:

$$\ddot{x} + \frac{e}{m} F_x + \omega_c \dot{y} = 0 \tag{12}$$

$$\ddot{y} + \frac{e}{m} F_y - \omega_c \dot{x} = 0 \tag{13}$$

$$\ddot{z} + \frac{e}{m} F_z = 0 \tag{14}$$

$$\epsilon_0 \frac{\partial F_x}{\partial t} + \rho \dot{x} = 0 \tag{15}$$

$$\frac{\partial H_z}{\partial x} + \epsilon_0 \frac{\partial F_y}{\partial t} + \rho \dot{y} = 0 \tag{16}$$

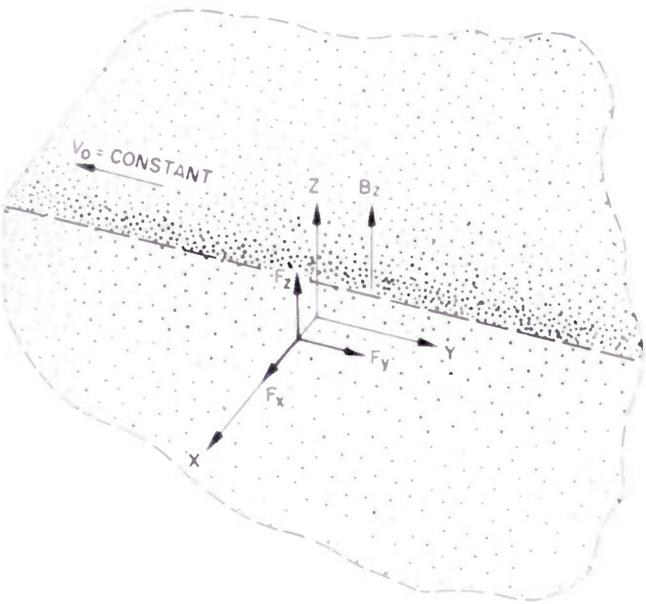
$$\frac{\partial H_y}{\partial x} - \epsilon_0 \frac{\partial F_z}{\partial t} - \rho \dot{z} = 0 \tag{17}$$

$$\frac{\partial H_x}{\partial t} = 0 \tag{18}$$

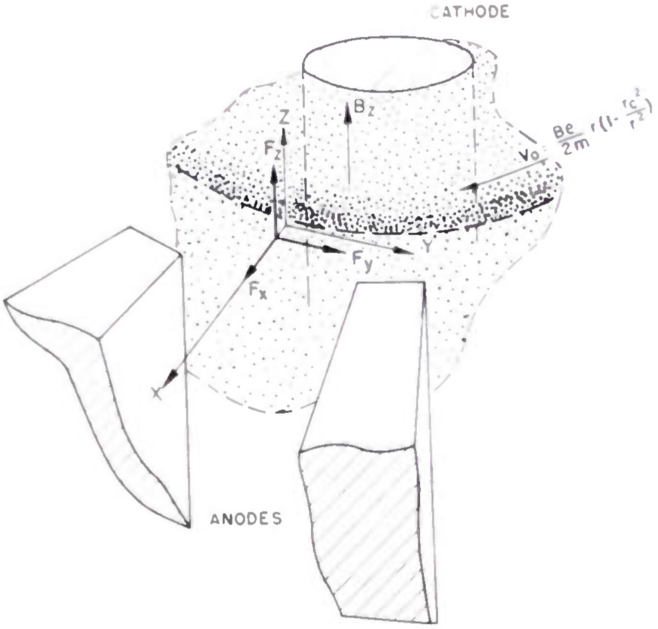
$$\frac{\partial F_y}{\partial x} + \mu_0 \frac{\partial H_z}{\partial t} = 0 \tag{19}$$

$$\frac{-\partial F_z}{\partial x} + \mu_0 \frac{\partial H_y}{\partial t} = 0 \tag{20}$$

$$\omega_c = B \frac{e}{m}$$ B is z-directed steady magnetic field.



(a)



(b)

Fig. 1—(a) Orientation of field vectors assumed for development of equation (22); space-charge swarm moving with uniform velocity. (b) Orientation of field vectors in magnetron space charge.

A solution of the type $Ae^{i(kx \pm \omega_f t)}$ is assumed for each of the quantities x, y, z, F_x, F_y, F_z, H_x, H_y, and H_z. ($\omega_f = 2\pi f$). A different constant A, of course, is used in each case. Substituting in (12) through (20) and differentiating, a set of simultaneous equations is obtained. The determinant of the coefficients in these equations is the following

x	y	z	F_x	F_y	F_z	H_y	H_z
$-\omega_f^2$	$\pm i\omega_f\omega_c$	0	e/m	0	0	0	0
$\mp i\omega_f\omega_c$	$-\omega_f^2$	0	0	e/m	0	0	0
0	0	$-\omega_f^2$	0	0	e/m	0	0
$\pm\rho$	0	0	$\pm\epsilon_0$	0	0	0	0
0	$\pm\rho$	0	0	$\pm\epsilon_0$	0	0	$+k/\omega_f$
0	0	$\pm\rho$	0	0	$\pm\epsilon_0$	$-k/\omega_f$	0
0	0	0	0	$+k/\omega_f$	0	0	$\pm\mu_0$
0	0	0	0	0	$-k/\omega_f$	$\pm\mu_0$	0

By Cramer's rule, in order for a solution other than a trivial solution to exist this determinant must be identically equal to zero.[4] It is convenient to solve for $k^2/\epsilon_0\mu_0\omega_f^2 = c^2/v^2$ where c = velocity of light and v = phase velocity of the wave. c/v is the effective index of refrac-

[4] See any advanced calculus text for discussion of this rule.

tion of the medium and c^2/v^2 therefore the effective relative dielectric constant ϵ_r. The result is

$$\epsilon_r = 1 + \frac{\rho e}{\epsilon_0 m} \frac{\left(\omega_f^2 + \frac{\rho}{\omega_0}\frac{e}{m}\right) - 1/2\omega_c^2(1 \mp 1)}{\omega_f^2\left(\omega_f^2 - \omega_c^2 + \rho\frac{e}{m}\right)}. \quad (21)^5$$

From (7) the space-charge density in a magnetron at the boundary of a swarm of radius r is

$$\frac{\rho e}{\epsilon_0 m} = -1/2\omega_c^2\left[1 + \left(\frac{r_c}{r}\right)^4\right] \quad (7a)$$

Letting

$$1 + \left(\frac{r_c}{r}\right)^4 = M,$$

the complete result for effective dielectric constant of the magnetron-type space charge may be written

$$\epsilon_r = 1 - \frac{M}{2}\frac{\omega_c^2}{\omega_f^2}\frac{\omega_f^2 - 1/2(M + 1 \mp 1)\omega_c^2}{\omega_f^2 - \omega_c^2\left(1 + \frac{M}{2}\right)}. \quad (22)$$

For the $(-)$ sign

$$\epsilon_r = 1 - \frac{M}{2}\frac{\omega_c^2}{\omega_f^2}\frac{\frac{\omega_f^2}{\omega_c^2} - \frac{M}{2}}{\frac{\omega_f^2}{\omega_c^2} - \left(1 + \frac{M}{2}\right)}. \quad (23)$$

For the $(+)$ sign

$$\epsilon_r = 1 - \frac{M}{2}\frac{\omega_c^2}{\omega_f^2}. \quad (24)$$

The result of (24) is exactly the same as the result which is obtained when no steady magnetic field is assumed present and is the result obtained in the paper by Blewett and Ramo, due to the neglect of the cross product of the radio-frequency velocity and the static magnetic field in the force equation.

Another case should be mentioned, which, although it does not occur in the conventional magnetron, is of importance in some structures which use the magnetron-type space charge to vary reactance for electronic frequency modulation. In this case the direction of wave propagation is assumed parallel to the direction of the magnetic field. This case is treated by the same method as the one just treated with the result

$$\epsilon_r = 1 - \frac{M}{2}\frac{\omega_c}{\omega_f}\frac{1}{\frac{\omega_f}{\omega_c} \pm 1}. \quad (25)^6$$

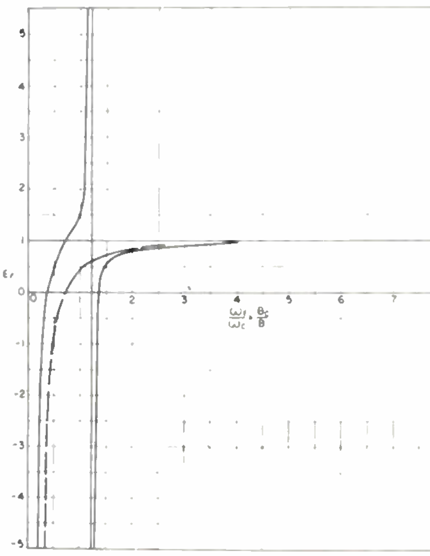
[5] It should be noted that the $(\pm)$ sign in this result is not a result of the assumption of a $(\pm)$ sign in the assumed solution but results from the quadratic nature of the solution of the determinant.

[6] In this case the $(\pm)$ sign is a result of the assumption that it exists in the exponential solution.

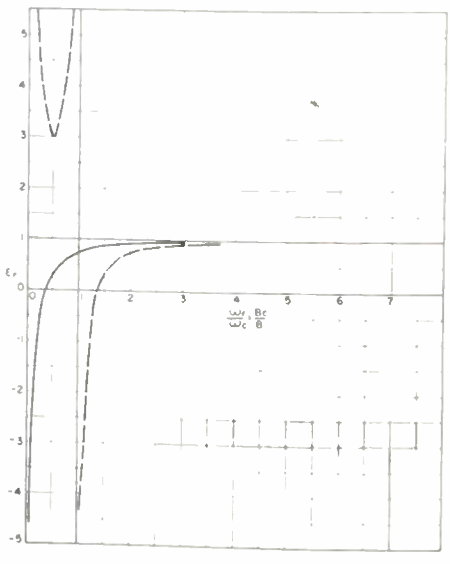
Equations (22) and (25) are plotted in Figs. 2(a) and 2(b) with the assumption that $M = 1$. This is approximately true only for values of r_c/r less than 1/3. The curves as plotted will, however, represent the picture with sufficient accuracy to support discussion.

The meaning of each of the various values of effective dielectric constant is not obvious from the development presented here. However, further examination of the polarizations of the waves and of a physical picture show the following to be true.

In Fig. 2(a) the solid curve from (23) corresponds to an electromagnetic wave polarized with the E vector perpendicular to the static magnetic field. The wave cannot be entirely transverse because there must be a component of E in the direction of propagation. The actual situation in an ideal multianode magnetron



(a)



(b)

Fig. 2—Dielectric constant of magnetron space charge as function of $\omega_f/\omega_c = B_c/B$. (a) Direction of propagation transverse to direction of magnetic field. (b) Direction of propagation same as direction of magnetic field.

should be approximated by this case as examination of Fig. 1(b) will show. If end effects are neglected, the electric fields are entirely in the xy plane perpendicular to the static magnetic field. However, propagation is not always perpendicular to $\vec{v}_0$.

In Fig. 2(a) the dotted curve from (24) corresponds to an electromagnetic wave polarized with the E vector parallel to the static magnetic field. In this case the presence of the magnetic field does not have any effect, as was pointed out previously.

In Fig. 2(b) the solid curve from (25) with + sign corresponds to an electromagnetic wave with left-hand circular polarization.

In Fig. 2(b) the dotted curve from (25) with − sign corresponds to an electromagnetic wave with right-hand circular polarization.

The effective dielectric constant, which is really a measure of phase velocity of the wave, depends on polarization, relationship of direction of propagation to direction of magnetic field, and value of ω_f/ω_c. The properties of these regions and the effect to be expected in a magnetron-type structure may be summarized as follows:

$\epsilon_r < 0$. In this case the phase velocity is imaginary; a wave will not propagate within the space charge; therefore, a space-charge boundary acts as a reflecting surface. The capacitance between cathode and anodes is increased by the presence of the space charge.

$0 < \epsilon_r < 1$. In this case the phase velocity of the wave exceeds the velocity of light. The capacitance between cathode and anodes is decreased by the presence of space charge.

$\epsilon_r > 1$. In this case the phase velocity of the wave is less than the velocity of light. The capacitance between cathode and anodes is increased by the presence of the space charge.

The total range of values covered by the graphs of Fig. 2 represents a considerable variation of conditions which might be imposed on the magnetron-type structure. Data exist only in limited regions; some of this will be presented in the next section.

It will be interesting at this point to compare these results with the results of Lamb and Phillips. In their paper the behavior near the cyclotron resonance is described from an impedance point of view for very small sheaths of electrons surrounding the cathode. This result is the following:

$$Z_{e1} \simeq \frac{F_\theta}{H} = \frac{in^2 s}{r_c^2 \epsilon_0 \omega_f} \frac{\omega_f^2}{\omega_c^2 - \omega_f^2} \tag{26}$$

where

F_θ/H = the ratio of the electric field vector to the magnetic field vector

s = thickness of the electron sheath around the cathode.

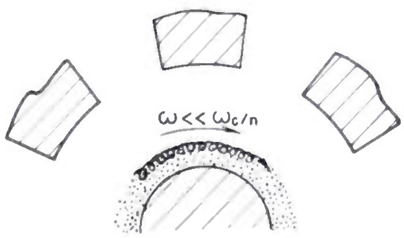
It is assumed that

$$\frac{ns}{r_c} < \frac{\omega_c^2 - \omega_f^2}{\omega_f^2} \quad \text{and} \quad n \neq 0.$$

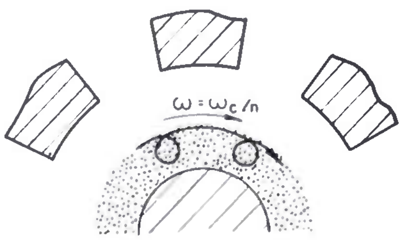
This restriction on the magnitude of s/r_c is a severe limitation in the practical case of an oscillating magnetron or frequency-modulation structure. In either of these cases, s/r_c can be an appreciable fraction of r_a/r_c. An effective cathode radius may be calculated which, when used as a boundary condition, obtains the same effect on resonant frequency of the anode block as the condition of (26). Thus

$$r_{ceff} = r_c\left(1 + \frac{2ns}{r_c} \frac{\omega_f^2}{\omega_c^2 - \omega_f^2}\right)\frac{n}{2}\cdot \tag{27}$$

This result predicts a resonance at the cyclotron frequency which is qualitatively described by a positive wavelength shift (capacitance increase) for $\omega_f/\omega_c < 1$ and a negative wavelength shift (capacitance decrease) for $\omega_f/\omega_c > 1$. This effect and the type of effects predicted by (23) might be simultaneously possible in an actual magnetron, since the assumptions involved in neither development can be held except in extreme cases. A qualitative picture of the behavior of the electrons near the cyclotron resonance is given in Fig. 3. In all cases the angular frequency impressed on the anode is assumed to be the cyclotron frequency. ω is the angular velocity of the outermost electrons. If



(a)



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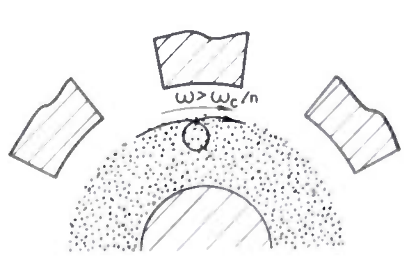


(c)

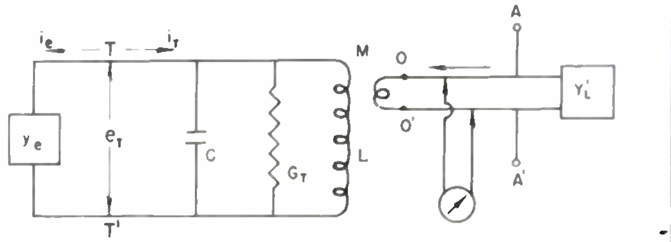
Fig. 3—Qualitative picture of cyclotron resonance.

$\omega \ll \omega_c/n$ (corresponding to small s), as in Fig. 3(a), the perturbed electron will execute several cycles in passing a set of anodes. In this case the resonance effect should occur very near the cyclotron frequency. The effect of the steady-state angular velocity is not important. If $\omega = \omega_c/n$, as in Fig. 3(b), the electron executes a single cycle in just the time it takes it to move, due to the steady-state velocity, from one set of anodes to the next. In the same time, the direction of the field between the next set of anodes has changed to be in phase with the electron oscillation. In the case of Fig. 3(c), the electron does not execute a single cycle in transit between two anodes and arrives between the next set out of phase with the field. Essentially these observations mean that the magnetic field for the cyclotron resonance should be a function of voltage. This has been observed experimentally and is presented in Fig. 10. To our knowledge more extensive data on the cyclotron resonance which might serve to clarify the picture do not exist.

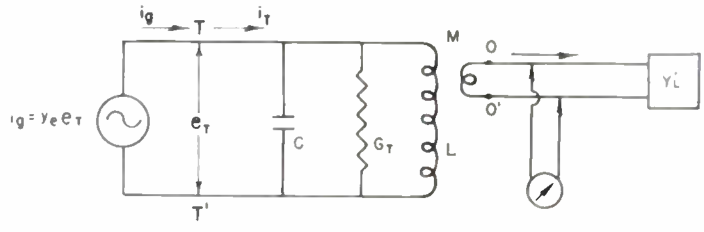
Space Charge and the Equivalent Circuit

The details of an equivalent circuit for a microwave device such as a magnetron naturally change with the structure of the magnetron. Effects of end hats, straps supporting structures, and the like may or may not be important enough to be included in the circuit. The equivalent circuit is usually based on the assumption that the various possible modes of oscillation are sufficiently separated in frequency to be considered individually. This permits the representation of the resonant circuit of the magnetron as a simple parallel resonant circuit. When this assumption is not valid, the resonance is made complex and, in general, must be treated as a special case. However, if the assumption is not justified, some sort of device is usually necessary to induce mode separation before the magnetron is practically usable. Thus, in most practical cases the simplified approach is adequate.

The most important concept in connection with equivalent circuits of magnetrons relative to the present problem is the concept of electron-transit admittance. It is the susceptive portion of this admittance which affects frequency characteristics of the magnetron. If an equivalent circuit may be established in which the function of the electron-transit susceptance is properly understood, the picture is greatly simplified. This has been done with satisfactory results for triodes, tetrodes and klystrons, but the picture in the case of magnetrons is still obscure. The circuit in Fig. 4(a) is suggested as equivalent in the case of a nonoscillating magnetron. In this circuit, the electron-transit admittance is represented by y_e which may be defined as the admittance of the electrons as seen from terminals representing the two sets of anodes. The nature of this admittance changes for various conditions of anode voltage, magnetic field, and radio-frequency voltage between anode segments. The primary purpose of this paper is to present the over-all picture of these changes. The picture for an oscillating magnetron is more complex. However, a convenient picture is obtained by replacing the admittance y_e by a current generator $i_g = y_e e_T$ (see Fig. 4(b)). The admittance y_e may now be thought of as the equivalent admittance of a current generator. The value of this admittance is a function of plate current and loading. Variation in the susceptive portion of this admittance with current is the cause of frequency pushing. This will be discussed in a following section.



(a)



(b)

Fig. 4—Equivalent circuits; arrow indicates direction of power flow. (a) Equivalent circuit for nonoscillating magnetron. (b) Equivalent circuit for oscillating magnetron.

Experimental investigation of the nature of the quantity y_e must be made by a meter located in the line between the output terminals O and O' and the load Y_L. In the case of the nonoscillating magnetron (Fig. 4(a)) an external signal must be fed into the circuit at the points A and A'. Measurements of standing-wave ratio and position of minimum, coupled with a knowledge of properties of the circuit and the controllable parameters in the circuit, yield an experimental result for y_e as a function of the variable parameters. This type of measurement we call a hot impedance test, in analogy with the established term, cold impedance test. When anode voltage is increased to the point of supporting oscillation, these measurements can no longer be made and the circuit in Fig. 4(b) applies. Standing-wave ratio and position of the minimum measurements now apply to the load. No external source is present. The load is therefore used as a variable and the effect on resonant wavelength, power output, and the like is recorded in the Rieke diagram. Variation of frequency with the plate current (frequency pushing) can be measured quite simply in connection with over-all performance data taken for constant loading.

In the case of the nonoscillating tube, a radio-frequency voltage may be considered applied across the capacitive portion of the magnetron circuit, at the boundary between the resonant circuit structure and the interaction space. This is represented by $T-T'$ in Fig. 4(a). The radio-frequency voltage causes a current i_T to flow into the tank circuit. If there are electrons present in the interaction space they may be represented by an admittance y_e through which a current i_e will flow. The currents i_e and i_T are independent of each other if the radio-frequency voltage is assumed unaffected by their magnitudes. If the admittance of the tank circuit is known, the admittance y_e could presumably be measured. This admittance should be dependent upon the values of magnetic field, anode voltage, radio-frequency voltage, and geometry of the interaction space.

In the case of the oscillating magnetron as represented in Fig. 4(b), the current i_T, developed in the tank circuit, is induced by spokes of synchronous space charge rotating in the interaction space. This current results in a radio-frequency voltage at the terminals $T-T'$. The current cannot exist until the oscillations become regenerative. The synchronous space-charge spokes cannot exist until radio-frequency voltages are present, i.e., until oscillation starts. The rotating spokes of synchronous space charge may be thought of as a current generator. There is a phase difference between the generated current and the radio-frequency voltage which causes the oscillations to build up at a lower frequency than the natural resonance frequency of the tank circuit. This phase difference and the equivalent negative conductance of the electrons are represented in y_e, the admittance equivalent to the generator representing the electrons. The value of this admittance must be such that the net susceptance and conductance of the circuit are cancelled at the frequency of oscillation. When the admittance characteristic of the tank circuit is known as a function of frequency near resonance, the value of y_e can be calculated.

These two interpretations of y_e should be kept in mind while reading the following sections. We will find that in the first case for the nonoscillating magnetron, the space-charge effects on frequency are primarily a function of the dimensions and density of the hub of the space-charge wheel. (See Fig. 13 for pictorial representation of the space charge.) In the second case of the oscillating magnetron, the effect on frequency is due to the phase relation of the spokes of synchronous space charge to the radio-frequency voltage. The two effects may cause frequency shifts in opposite directions. Quantitative agreement between experiment and theory for the first case is shown in the Appendix. In the second case, only qualitative discussion is thus far possible.

Space-Charge Effects in the Nonoscillating Magnetron

In order to measure effects of space charge in the nonoscillating magnetron, hot impedance measurements must be made from the output terminals. The measurements which have been taken are of four types as follows:

1. Impedance measurements at constant magnetic field and radio-frequency voltage, anode potential as variable parameter.
2. Impedance measurements at constant magnetic field and anode potential, radio-frequency voltage as variable parameter.
3. Resonant wavelength measurements at low radio-frequency voltage for different magnetic fields, anode potential as variable parameter.
4. Resonant wavelength measurements at low radio-frequency voltage and constant space-charge swarm radius, magnetic field as variable parameter.

A schematic drawing of the experimental setup is shown in Fig. 5. In order to obtain high radio-frequency voltage, one magnetron is used to drive another. Radio-frequency voltage is varied by means of attenuating reflectors placed in a slotted section between

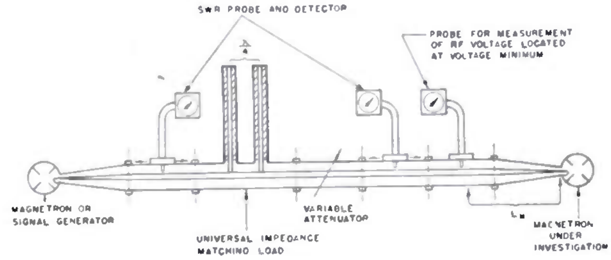


Fig. 5—Experimental apparatus for hot impedance heating.

the impedance matching load and the magnetron under investigation. Radio-frequency voltage is measured by a probe placed at a voltage minimum (at cold resonance) approximately three wavelengths from the magnetron coupling loop (L_M in the diagram). This probe leads to a crystal detector and microammeter. The probe is calibrated against power measurements into a matched load and radio-frequency voltage calculated from the known line impedance of 52 ohms. The impedance matching load is quite useful for measurements of this type or in any application where a high-Q circuit is to be driven by a magnetron. It consists of two loads separated by $\lambda/4$. The driving magnetron is thus under no circumstances subject to standing-wave ratios greater than three to one.

In the impedance measurements, Q_0, λ_0 and G_0 are measured and plotted against the variable parameter, Q_0 is the unloaded Q of the magnetron, λ_0 is the resonant wavelength, and G_0 is the input conductance at resonance. $G_0 = Y_0/\sigma_0$, where σ_0 is the minimum standing-wave ratio and Y_0 is the characteristic admittance of the line

The results of hot impedance measurements made under various conditions are shown in Figs. 6 through 12. The results shown in Fig. 6 offer a comparison between frequency effects in the nonoscillating magnetron and in the oscillating magnetron. The increasing reso-

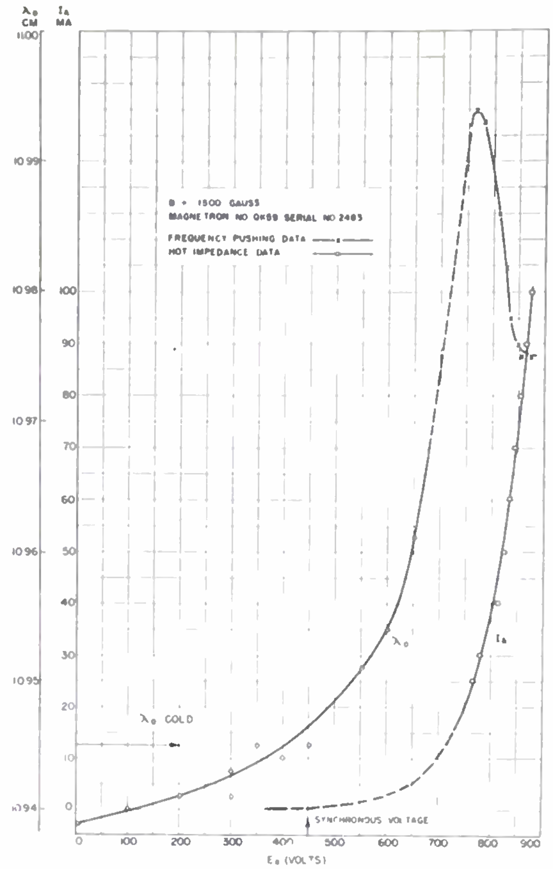
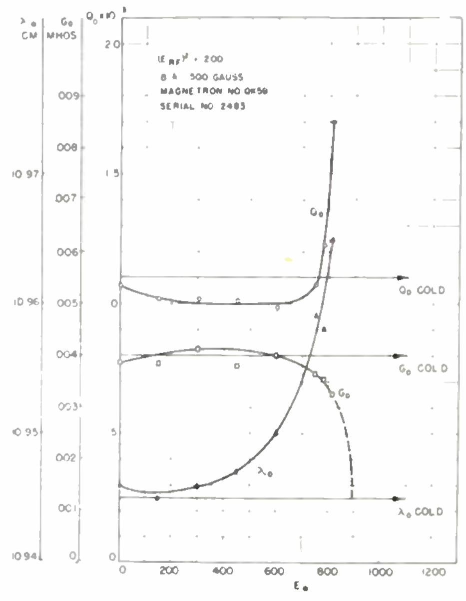


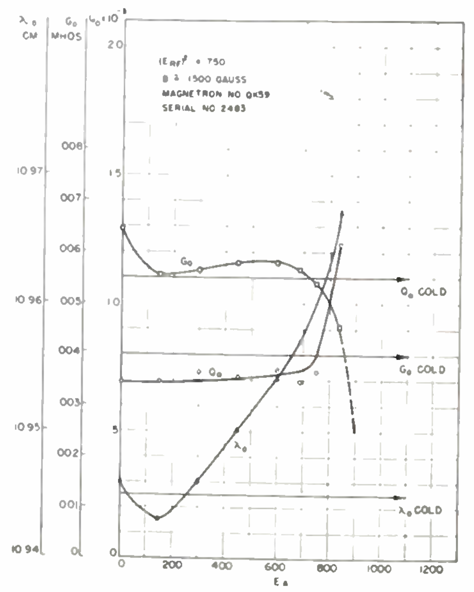
Fig. 6—Change of magnetron resonant wavelength with plate voltage. Comparison of frequency pushing and hot impedance test results.

nant wavelength up to the voltage for which synchronism begins (450 volts) is due to the capacitance between anodes increasing as a cloud of electrons of negative dielectric constant expands within the anode structure. This is what may be called a passive effect of the electrons. Above this point synchronous reactance causes a sharp rise in wavelength, and when oscillation starts the direction of wavelength shift reverses. The original cold resonant wavelength is not reached. This reversal effect is called frequency pushing, and may be called an active effect of the electrons. Frequency pushing and synchronous reactance will be discussed qualitatively in the next section. The passive effects in the preoscillating region can be discussed more quantitatively. This is done in the Appendix in terms of the data on tubes built in the Michigan laboratory.

In Fig. 7 the variation of λ_0, Q_0 and G_0 is plotted against plate voltage for two values of radio-frequency voltage impressed upon the anode structure. The general form of the curves is seen to be the same, with a reduction in Q as the radio-frequency voltage is raised. The Q_0 curves are relatively flat up to about 700 volts. This indicates that there is no change in the conductive characteristics of the space charge in this region. At about 700 volts, the Q_0 begins to rise sharply. At the point of oscillation it would, ideally, go to infinity as the conductance goes to zero. This point occurs at about 900 volts. This behavior means that in the region between 700 and 900 volts space charge is contributing energy to the radio-frequency field and therefore synchronous bunches of space charge have been formed. When the Q_0 curve intersects with the cold Q_0 line the space charge is contributing just enough negative conductance to compensate for losses which may be present within the space charge due to bombardment of the cathode and collisions with large ions. The further increase in Q_0 represents compensation for copper losses in the resonant circuit. The reduction of the Q_0 in the flat portion of the curve is due to increase in losses due to back bombardment as radio-frequency voltage is raised. The data in Fig. 8 show how the Q_0 varies with radio-frequency voltage for a value of anode voltage in the flat portion of the curve of Fig. 7. The losses are



(a)



(b)

Fig. 7—Q_0, λ_0, and G_0 of hot magnetron as a function of plate voltage for various radio-frequency voltages.

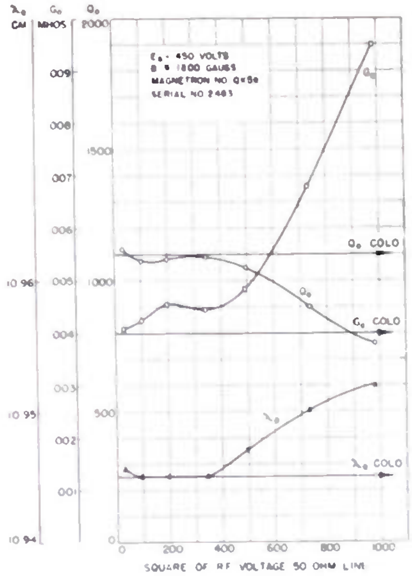


Fig. 8—Q_0, λ_0, and G_0 of hot magnetron as function of radio-frequency voltage for constant plate voltage.

going up rather rapidly with the increasing radio-frequency voltage. This is probably due to an increase in the energy spent in back bombardment of the cathode.

The complexity of the space-charge frequency characteristics in the nonoscillating magnetron when a wide range of variables is considered is clearly illustrated by the four sets of data in Fig. 9. These data were taken by an absorption method in which resonance was observed on an oscilloscope pattern. Q measurements could not be made. The radio-frequency voltage was supplied from a klystron signal source. The curves are similar to those just discussed except that E/B^2 is used as the independent variable. The radius of the space-charge swarm, in the absence of radio frequency, is proportional to this quantity. In the presence of radio frequency there are three critical conditions involving magnetic field and voltage; these are expressed by (28), (29), and (30) which follow. The critical values are noted on the curves of Fig. 9.

$$\omega_c \cong \frac{B_c e}{m} \tag{28}$$

where

$$\omega_c = \frac{2\pi c}{\lambda_c}$$

$$c = \text{velocity of light.}$$

This equation defines the cyclotron resonance. λ_c is the critical wavelength for the particular magnetic field B_c at which the period of natural rotation of an individual electron in the magnetic field is equal to the period of the radio-frequency cycle. As was pointed out in the discussion of Fig. 3 the resonance in the magnetron space charge should also be a function of voltage. This is borne out in the results shown in Figs. 9(b)

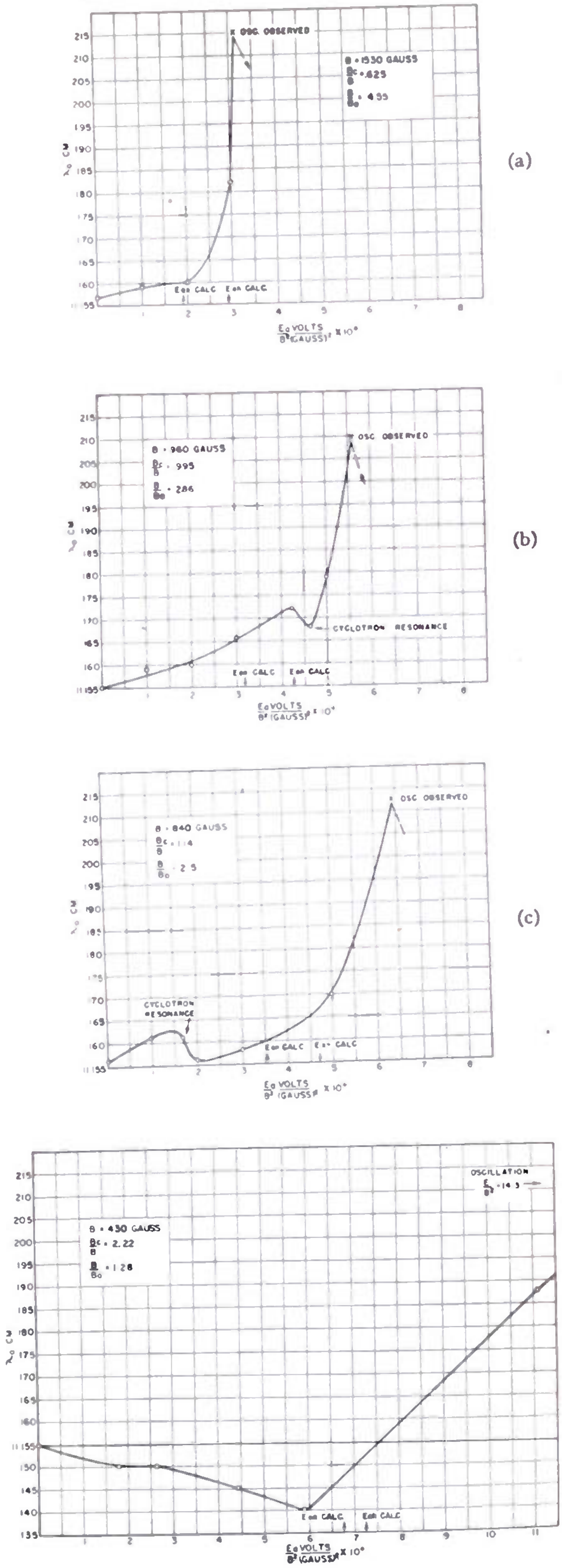


Fig. 9—Hot impedance test on QK59 no. 2483.

and 9(c) where the cyclotron resonance shows up as a perturbation of the resonant wavelength for two different voltages at slightly different magnetic fields.

chronous electrons can reach the anode with no radially directed velocities (Hartree voltage). This voltage is approximately the voltage at which oscillations begin.

$$\frac{E_{an}}{E_0} = \frac{B_n}{B_0} \frac{r_c^2/r_a^2}{\frac{B_n}{B_0} - \left(1 - \frac{r_c^2}{r_a^2}\right)} \left[2\left(\frac{B_n}{B_0} \frac{2}{1 - \frac{r_c^2}{r_a^2}} - 1 \right) \log \frac{\sqrt{\frac{B_n}{B_0} - \left(1 - \frac{r_c^2}{r_a^2}\right)}}{\frac{r_c}{r_a}\sqrt{\frac{B_n}{B_0}}} + 1 \right] \tag{29}$$

where

$$E_0 = \frac{m}{2e}\omega_n^2 r_a^2$$

$$B_0 = \frac{2m}{e}\omega_n \frac{1}{(1 - r_c^2/r_a^2)}$$

(ω_n defined in (11)).

Equation (29) relates the anode voltage (E_{an}) and magnetic field (B_n) for which outer electrons in the space-charge swarm reach a velocity synchronous with the angular velocity of the radio-frequency wave traveling around the interaction space. For higher voltages than E_{an} the electrons are trying to move faster than synchronism and can give energy to the radio-frequency field. This condition shows up as a contribution of negative conductance and positive susceptance to the system, thus causing a rather sharp increase in Q and resonant wavelength.

$$\frac{E_{ah}}{E_0} = 2\frac{B}{B_0} - 1. \tag{30}$$

This equation defines the anode voltage at which synchronous electrons can reach the anode with no radially directed velocities (Hartree voltage). This voltage is approximately the voltage at which oscillations begin.

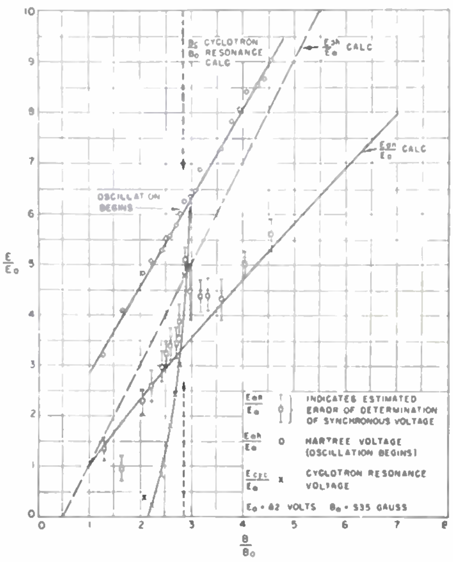


Fig. 10—Summary data on QK59 no. 2483 illustrating equations (28), (29), and (30).

Fig. 10 presents summary data of these three conditions extracted from a group of 26 curves similar to those of Fig. 9. The calculated values are presented for comparison. A considerable spread is represented for points on the curve for E_{an}/E_0, since the point at which a sudden increase in resonant wavelength occurs on the experimental curves is not definite.

The observed starting voltage seems to bear a definite relation to the calculated Hartree voltage, since the slopes of the two curves are approximately the same. The difference is probably due to the effect of the load on the starting voltage. This has not been quantitatively analyzed, but it may be said that, in a given magnetron, as the Q is lowered the starting voltage is raised.

The critical magnetic field for the cyclotron resonance is quite obviously affected by voltage. No satisfactory theory has been developed to give quantitative explanation of this effect. The synchronous voltage checks very well, considering the region of doubt which exists in its determination It seems to be strongly perturbed in the region of the cyclotron resonance. It is interesting to note, however, that the cyclotron resonance seems to have no particular effect on the starting voltage for oscillation.

The static cutoff voltage (given by (2) with $r = r_a$) is calculated to be $E/B^2 = 7.4$. It is quite obvious in Fig. 9(d) and several other sets of data which are not given that this is not checked for low magnetic field in this particular magnetron.

In order to observe effects on resonant frequency due only to the change in effective dielectric constant of the space-charge swarm (as given by (23)), it is necessary to use data taken at various magnetic fields and at constant swarm radius. It is also necessary to stay below the voltage required to produce synchronous electrons. Thus, data in the curves of Fig. 9 taken below the synchronous voltage should represent the effect due to to the expansion of a space-charge swarm having an effective dielectric constant determined by $B_c/B = \omega_f/\omega_c$. Wavelength shift for four values of E/B^2 and varying B is plotted in Fig. 11. The position of the observed cyclotron resonance and the calculated field required for synchronism are marked. The latter is given by

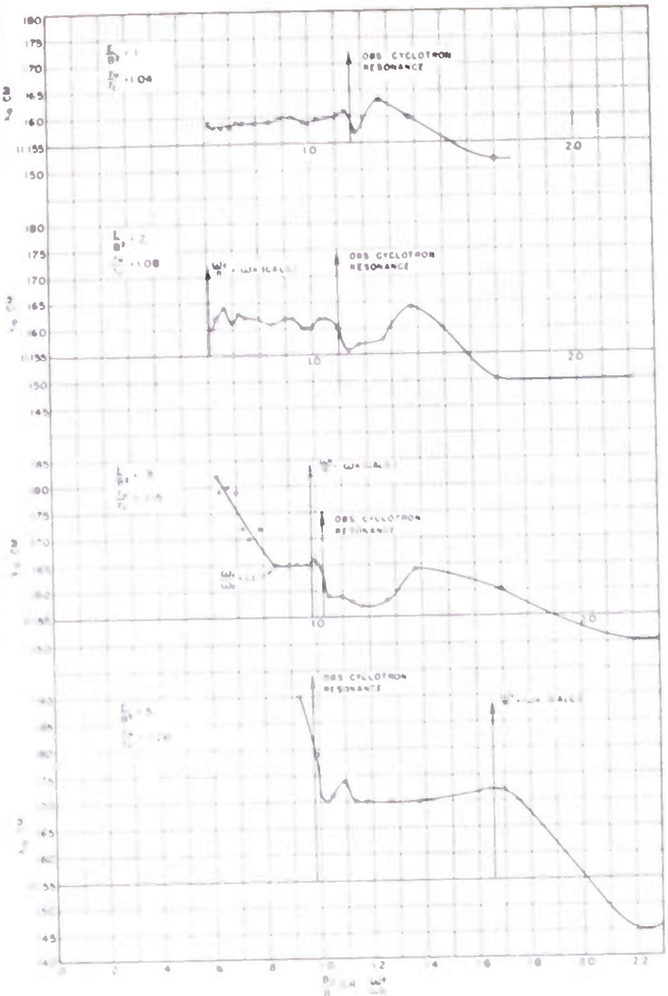


Fig. 11—Hot impedance test on QK59 no. 2483.

$$\frac{R_n}{R_0} = \frac{1 - \dfrac{r_c^2}{r_a^2}}{1 - \dfrac{r_c^2}{r_n^2}}. \tag{31}$$

For $\omega_f/\omega_c < \omega_f/n\omega_n$ the outer electrons in the swarm are tending to travel with greater than synchronous velocities and can contribute synchronous reactance which masks the effect of changing dielectric constant. The curve for $E/B^2 = 2$, $r_H/r_c = 1.08$ is replotted in Fig. 12 with the effective dielectric constant as given by (23). The expected wavelength shift (with amplitude arbitrarily adjusted to equal the observed shift) is shown by the dotted line. Agreement seems to be good except in the region between $\omega_f/\omega_c = 0.575$ and the observed cyclotron resonance. This may be due to the fact that the electrons are approaching synchronous velocities.

The over-all qualitative picture presented by these data is fairly clear, while attention to particular points may be misleading because of experimental inaccuracies or insufficient theoretical understanding. Some of the important conclusions are summarized below, and quantitative results for some particular cases are given in the Appendix.

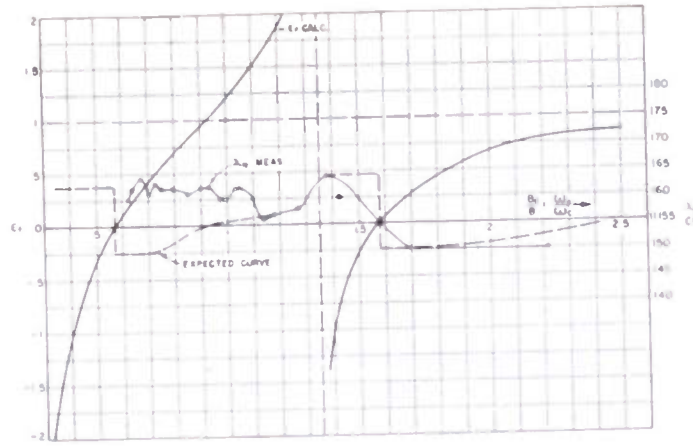


Fig. 12—Effective dielectric constant for magnetron space charge compared with wavelength shift for $r_H/r_c = 1.08$.

The three types of effects on frequency are clearly represented by the data.

1. Passive effects due to wave-propagating properties are illustrated as wavelength shift at subsynchronous voltages in Fig. 9 and to the right of the lines $\omega_f/n = \omega_n$ in Fig. 11. The subsynchronous data in Fig. 9(a) illustrate increasing wavelength for $\epsilon_r < 0$ and in Fig. 9(d) decreasing wavelength for $0 < \epsilon_r < 1$. The curves in Fig. 12 which pertain to these effects have been discussed in the last paragraph.

2. Synchronous reactance is demonstrated by the relatively sharp increase in wavelength above synchronous voltage and to the left of the line $\omega_f/n = \omega_n$ in Fig. 11. The case for $E/B^2 = 5$ is particularly interesting in this connection. The decrease in wavelength showing up in the other curves between $B_c/B = 1.05$ and $B_c/B = 1.35$ is apparently cancelled by the effects of synchronism. This shows up even more clearly upon careful examination of data of the type shown in Fig. 9 from which this curve was taken. Synchronous reactance will be discussed more completely in the next section.

3. The cyclotron resonance shows up quite obviously in Figs. 9(b), and 9(c), and is, as would be expected, dependent upon anode voltage. It is not clear from the data whether this point is intimately related to the other two effects. It does appear in Fig. 11 that a sharp increase in wavelength with increasing magnetic field should be associated with the cyclotron resonance.

The most probable sources of error are the following:

Magnetic field for the entire series of measurements may be off by 75 to 100 gauss. It is fairly certain that the calibration was not changed during the series of measurements, because it was possible to recheck critical points at the cyclotron resonance and starting voltage.

Dimensions of the magnetron, particularly r_a/r_c, may be in error by 10 to 20 per cent. Another tube which was taken apart had a cathode larger in this proportion. The dimensions used were taken from data in the tube specifications.

Wavelength measurements were made with a Mico wavemeter. The estimated error is ±0.002 cm. The direction of wavelength shift could always be observed by watching the oscilloscope screen. Determination of the exact resonant wavelength near the cyclotron resonance was difficult because of the distortion of the scope pattern.

Space-Charge Effects in the Oscillating Magnetron

Evidence of space-charge effects in the oscillating magnetron is given in the results of frequency-pushing measurements and in Rieke diagrams. Space-charge effects on frequency in the conventional oscillating tube are of small magnitude, of the order of 1 per cent. Frequency pushing is ordinarily defined as variation of oscillatory frequency with plate current, in contrast with the term frequency pulling, which is, ideally, variation of frequency at constant standing-wave ratio in the Rieke diagram.

More generally it is convenient to think of frequency variation over a performance chart (set of volt ampere characteristics at varying magnetic fields and constant load) and frequency variation with variation in load impedance at constant current and magnetic field as is experienced in the Rieke diagram. Variation of frequency over the performance chart is entirely due to space-charge effects. Variation of frequency in the Rieke diagram is primarily due to changes in the susceptive portion of the load impedance. However, contours of constant frequency in the Rieke load-impedance diagram should follow contours of constant susceptance. The fact that this is not the case may be attributed to space-charge effects.

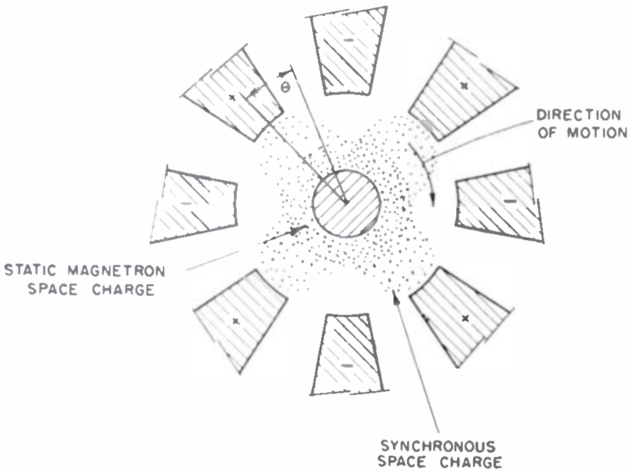


Fig. 13—Pictorial representation of space charge within interaction space.

Fig. 13 presents a qualitative picture of the space-charge swarm with spokes at an instant when the anodes are at their maximum + or − radio-frequency potential. The spokes form on the static magnetron space-charge swarm bounded by the synchronous radius (which can be calculated from (31)). In the nonoscillating magnetron with imposed radio-frequency, as described in the last section, the spokes can form without reaching all the way out to the anode. The maximum radius reached in the spoke is determined by the anode potential, and the spoke will form in the region of the maximum positive potential, 90 electrical degrees ahead of the maximum decelerating field. Thus the current induced by the rotating spokes will lead the radio-frequency voltage by approximately 90 degrees. As the anode potential is increased the spoke will extend farther toward the anode, maintaining the same phase position but increasing the amount of susceptance contributed by the space charge. This accounts for the sharp rise in resonant wavelength before oscillation starts, exhibited in the curves of Figs. 6 through 9. When oscillation starts, the spokes must reach out of the anodes and there is a transport of electrons through the spokes sufficient to supply the dc anode current necessary to provide input power. The generated frequency is usually lower than the frequency of the tank circuit by a margin of the order of $1/Q$. The impedance of the tank circuit is almost a pure inductance and the power delivered from the electron swarm is small. In order for more power to be delivered from the spokes to the circuit the angle θ must be reduced so that the induced current leads the voltage less than 90 degrees. As the voltage is raised further, the phase angle is reduced further, thereby decreasing the positive susceptance contributed by the spokes and decreasing the resonant wavelength. Fig. 6 illustrates this effect. The dotted lines in Fig. 9 also indicate the direction of wavelength shift after oscillation was observed.

The fact that the resonant wavelength does not come back to the cold resonance value may be due to the presence of the hub of subsynchronous space charge. It is important to realize that variation in frequency over the performance chart may depend upon the "passive" effects of the hub of the space-charge wheel as well as the "active" effects of the spokes. Therefore, a complete analysis of pushing data would be more complex than the relatively simple interpretation just given.

The difference in the physical significance of the quantity y_e in the preoscillating and oscillating magnetron as discussed in connection with Fig. 4 is apparent in the above discussion. In the former case, expansion of the hub and synchronous spokes have the major effect, with some complication introduced by the cyclotron resonance. In the latter case, the effect of the hub is probably a constant correction, whereas the phasing of the spokes with respect to the radio-frequency wave in the interaction space makes a major contribution.

Space-charge effects in the Rieke diagram are intimately related to frequency pushing. The rotating swarm is thought of as a current generator, the frequency of which is a function of power output. Power output in turn is a function of the load on the generator. The experimental evidence of Rieke diagrams indicates the electronic susceptance to be a function of the load conductance on the magnetron. Variation of the conductive portion of the magnetron load without change in the susceptive portion varies the form of the resonance curve without changing its position on the frequency axis. The rotating swarm of electrons must adjust itself to meet the conditions of negative conductance and phase relationship to the radio-frequency voltage imposed by the resonant circuit. In addition, the changing radio-frequency voltage caused by variation in load will react on the electron swarm. This combination of causes must have a very complex, but not very large, effect upon the frequency of oscillation. Further complication results from the fact that a particular value of load conductance (a particular form of the resonance curve) allows maximum efficiency of energy transference from the electron swarm to the radio-frequency field. This is the condition of optimum shunt impedance. The characteristics of the optimum condition are understood for conventional oscillators employing triode or tetrode vacuum tubes, but still not satisfactorily explained in the case of the magnetron oscillator.

Conclusions

The present paper is not meant to be a complete and final analysis of the problem of the magnetron space-charge and frequency characteristics. It is intended to relate as many as possible of the known facts and theories in such a way that it can be used as a guide for further research and development. We have presented in some detail the ideas and data originating in the University of Michigan laboratory and have tried to provide enough discussion and criticism of other ideas to make the development consistent.

Some important conclusions have been mentioned in the discussion of the experimental results and theory. These are the following:

1. Frequency pushing with increasing voltage is primarily due to a decrease in wavelength caused by the active phasing effect of the electrons in the spokes of the space-charge wheel acting as a current generator in the magnetron.

2. The increase in the extent of space-charge spokes as voltage is increased under hot impedance test conditions may also contribute an increasing positive susceptance without change in the phase angle of the spoke relative to the wave of radio-frequency potential.

3. Frequency shifts caused by the subsynchronous swarm as voltage is increased under hot impedance test conditions are primarily of two types. In one case, the dielectric constant of the hub of the space-charge wheel is negative and the resonant wavelength increases as the hub expands. In the other case, the dielectric constant of the hub of the space-charge wheel is positive, but less than unity, and the wavelength decreases as the hub expands. These effects may be called passive effects.

4. For a particular value of magnetic field, under hot impedance test conditions, the natural resonance of the individual electrons in the space charge causes perturbation of the resonant wavelength. This is the cyclotron resonance ($\omega_f = \omega_c$).

5. Frequency pulling is primarily an effect of circuitry. Deviations from the values predicted on the basis of circuitry are due to interrelation of the equivalent susceptance and conductance of the space-charge cloud acting as a current generator in the magnetron. They are therefore related to frequency pushing.

It would be desirable to amplify experience by carrying out experiments designed to determine the exact value of y_e, the electronic admittance, under various conditions in both the nonoscillating and the oscillating cases. Possibly, if enough data were available on different magnetrons, generalizations could be made which would give more insight into the actual behavior in the oscillating magnetron. It is important to realize that, although the frequency shifts due to space-charge effects are small compared to the resonance frequency (of the order of one per cent), an understanding of the underlying causes of these shifts is equivalent to an understanding of the basic electronic principles of magnetron operation.

Frequency shifts of the type mentioned in 3 and 4 above may be used in a reactance tube to produce frequency modulation. The problem of designing a tube of this type has been undertaken in the University of Michigan laboratory. Details of this development will be presented when data are available on operating tubes. Quantitative results and a simple formula, placing limitation on the design of such tubes with multianode structures, are given in the Appendix.

Appendix

The theory and experimental results given in this paper can be used as a basis for design in devices using the magnetron-type space charge to furnish electronic control of frequency. Frequency shifts of the order of 8 per cent of 500 Mc have been obtained using split-anode magnetrons.[7] The space charge may be used within a multianode structure attached to the resonant circuit of the magnetron. The theory which has been developed can be used as a basis for convenient design criteria by which anode structure and interaction space designs can be determined which obtain maximum benefit of the space charge and do not permit oscillation.

In the first place, if we wish to make use of the properties of a space charge of negative dielectric constant, we have the condition

$$\omega_f < 0.36\omega_c. \tag{32}$$

This is obtained from Fig. 2. If we wish to place the

[7] These results were obtained by P. H. Peters at the General Electric Research Laboratories.

further restriction that magnetron does not oscillate, we have the well-known condition

$$B < B_0. \tag{33}$$

If (32) and (33) are combined so that the structure will not oscillate and the space charge will cause total reflection, we obtain the following:

$$\omega_f < 0.36\omega_c = 0.36 \frac{Be}{m} < 0.36 \times B_0 \frac{e}{m}$$

$$= 0.36 \times \frac{2\omega_f}{n} \frac{1}{1 - \frac{r_c^2}{r_a^2}}$$

which results in the simple criterion

$$1 - \frac{r_c^2}{r_a^2} < \frac{0.72}{n}$$

or

$$\frac{r_a}{r_c} < \sqrt{\frac{1}{1 - 0.72/n}}. \tag{34}$$

This last equation gives the following values of r_a/r_c for various values of n:

$n = 1$	$r_a/r_c < 1.88$
2	1.25
3	1.15
4	1.10
5	1.08
6	1.06.

Spacing requirements imposed a limitation on the value of r_a/r_c which can be used and, therefore, on n. For example, if the cathode diameter is of the order of $\frac{1}{2}$ to 1 centimeter, $r_a/r_c < 1.15$ begins to be impractical. Therefore, $N = 2n = 6$ is the largest practical number of anodes. To be on the safe side, $N = 4$ or even $N = 2$ should be used if possible.

If it is desired to make use of the space charge with a positive dielectric constant less than unity the following criterion may be used:

$$\omega_f \mathrel{\tilde{>}} 1.36\omega_c. \tag{35}$$

ω should not be too much in excess of ω_c; otherwise ϵ_r differs so little from unity that the change in susceptance due to the space charge will not be appreciable. At most, the presence of space charge of these characteristics can do no more than cancel the effect of the cathode. The value of ω_f/ω_c might arbitrarily be limited to less than two for this case. If this is done, we have as before

$$1 - \frac{r_c^2}{r_a^2} < \frac{4}{n}$$

or

$$\frac{r_a}{r_c} < \sqrt{\frac{1}{1 - 4/n}}. \tag{36}$$

This imposes no serious restriction on r_a/r_c and is actually satisfied in most conventional continuous-wave magnetrons operating at wavelengths greater than 6 centimeters.

The relative merits of these two types of behavior under conditions of high radio-frequency voltage are not yet experimentally determined. On paper the use of space charge of negative dielectric constant can produce an infinite change in λ_0, whereas the space charge of positive dielectric constant can only cancel the effect of the cathode. This latter, of course, can be two to five per cent. The linearity of frequency change and losses under the influence of high radio-frequency voltage might give preference to the latter method. This remains to be seen. The following illustrative cases give quantitative comparison of experimentally observed results with the theory.

The total capacitance in the resonant circuit of any magnetron must include the capacitance between anode and cathode. The latter is the portion which is varied by the presence of the space charge. Let

C_a = total anode-to-anode capacitance including effect of cathode
C_c = total anode-to-cathode capacitance
ΔC_c = change in anode-to-cathode capacitance caused by presence of space-charge swarm.

For a given ΔC_c it can be shown that the resonant wavelength shift is given approximately by

$$\frac{\Delta\lambda_0}{\lambda_0} = \alpha \frac{C_c}{C_a} \frac{\Delta C_c}{C_c}. \tag{37}$$

Here α is a proportionality factor which is equal to $\frac{1}{2}$ in a lumped-constant circuit since, in this case, wavelength is proportional to the square root of the capacitance. In distributed-constant circuits, as is usually the case in a magnetron, α is less than $\frac{1}{2}$ and must be calculated for the particular case.

C_c/C_a is ordinarily four or five per cent. By particular design it can be made 20 per cent or more.

The method of calculation of $\Delta C_c/C_c$ varies with the geometry and the effective dielectric constant of the space charge. The following two examples are typical.

If $0 < \epsilon_r < 1$ and the space between anode and cathode is just filled by the space-charge swarm (thus having maximum effect),

$$\frac{\Delta C_c}{C_c} = \epsilon_r - 1 \tag{38}$$

where, since ϵ_r is less than unity, the wavelength shift is always negative and the maximum value of shift corresponds to $\Delta C_c/C_c = -1$. In this case the effect of the cathode is cancelled. Table I gives two sample calculations for this case. ϵ_r is calculated from (23).

In the case of negative ϵ_r, total reflection should occur from the space charge. The cathode diameter is therefore effectively increased by the presence of the space charge. The capacitance between anode and cathode will be a function of the following form:

$$C_c = \frac{K}{\ln r_a/r_c} \tag{39}$$

where K is a function of r_a/r_c because of fringing effects around the anodes. The percentage change in effective capacitance to the cathode is therefore the following, if we consider r_H (radius of the space-charge cloud) as a reflecting surface:

$$\frac{\Delta C_c}{C_c} = \frac{\dfrac{K_H}{\ln r_a/r_H} - \dfrac{K_c}{\ln r_a/r_c}}{\dfrac{K_c}{\ln r_a/r_c}}$$

$$\frac{\Delta C_c}{C_c} = \frac{K_H \log r_a/r_c}{K_c \log r_a/r_H} - 1. \tag{40}$$

Using this result in (37), the following result were obtained in two different tubes constructed in the University of Michigan laboratory. In the second case, a negative dielectric constant is actually not predicted by the theory, but the direction of wavelength shift indicates that the space charge is reflecting. This sort of discrepancy may be due to errors in determination of magnetic field or to the oversimplified nature of the theory.

In the optimum design of a modulator tube, α should be made as large as possible. The second case of Table II illustrates this point. Although a capacitance change of 123 per cent is obtained, due to the small value of α, the wavelength shift is less than one per cent.

Acknowledgments

The author is indebted to all of his co-workers in the University of Michigan Electron Tube Laboratory, particularly to W. G. Dow, who suggested the technique of hot impedance testing, and to J. R. Black, G. R. Brewer, and Miss Rita Callahan, who offered many helpful suggestions and assisted in gathering of experimental information.

TABLE I

Comparison of Theory and Results for $0<\epsilon_r<1$ in the Space-Charge Swarm

E_a volts	B gauss	λ cm	r_a/r_c	r_H/r_c	ω_f/ω_c	C_c/C_a	α	ϵ_r-1 $(\Delta C_c/C_c)$	$\Delta\lambda_0/\lambda_0$ Calculated	$\Delta\lambda_0/\lambda_0$ Observed
190	210	16.85	1.66	1.66	3	0.045	0.5	−0.07	−0.16 per cent	−0.18 per cent
450	450	17.6	1.66	1.66	1.35	0.045	0.5	−1	−2.25 per cent*	−1 per cent

* Note from the solid curve in Fig. 2(a) that ϵ_r is a very critical function of magnetic field in this region so that a 1-per cent error in determined field could produce almost a 100-per cent error in the calculated wavelength shift.

TABLE II

Comparison of Theory and Results for $\epsilon_r<0$ in the Space-Charge Swarm

E_a volts	B gauss	λ cm	r_a/r_c	r_H/r_c	ω_f/ω_c	C_c/C_a	α	$\Delta C_c/C_c$	$\Delta\lambda_0/\lambda_0$ Calculated	$\Delta\lambda_0/\lambda_0$ Observed
1,400	1,700	16.9	1.66	1.11	0.35	0.045	0.5	+0.25	+0.55 per cent	+0.65 per cent
1,400	1,400	13.2	1.33	1.17	0.58	0.05	0.125*	+1.23	+0.77 per cent	+0.76 per cent

* These data were taken on a double-anode modulator tube with a distributed constant circuit—hence the low value of ω. All other data were taken on an interdigital magnetron in which the capacitance was essentially concentrated in the anodes.

Comparison of Tropospheric Reception at 44.1 Mc with 92.1 Mc Over the 167-Mile Path of Alpine, New Jersey, to Needham, Massachusetts*

GREENLEAF W. PICKARD†, FELLOW, IRE, AND HARLAN T. STETSON†, ASSOCIATE, IRE

IN A PREVIOUS paper,[1] the authors rendered an account of field intensity measurements of W2XMN at 42.8 Mc made at the Cosmic Terrestrial Research Laboratory at Needham, Mass., during 1945 and a part of 1946, and exhibited certain relations found with meteorological conditions. On January 24, 1947, the frequency of W2XMN was changed from 42.8 Mc to 44.1 Mc, and in the summer of that year a higher frequency was transmitted from the same tower at Alpine as station W2XEA at a frequency of 92.1 Mc with substantially equal power on both frequencies. This gave an opportunity for making comparative measurements on both the higher and lower frequencies over the same path of Alpine, N. J., to Needham, Mass., 167 miles in length, or 270 kilometers.

Records of W2XEA began on August 15, 1947 on the same schedule as W2XMN 1600–2300 Eastern Daylight Standard Time in summer and Eastern Standard Time in winter. The general picture of Alpine reception from these two stations as received at Needham is that the fields vary widely from second to second, and even from minute to minute. However, when reduced to microvolts/meter, the two fields received at Needham show similar variations with respect to daily and monthly values. The average field of the higher frequency (92.1 Mc) exhibits somewhat higher values than the fields of the lower frequency station.

The authors find variations in both of these fields closely correlatable with atmospheric refraction throughout the interval as determined from calculation of surface refraction utilizing meteorological data obtained at Boston. Meteorological data at New York or Hartford proved less satisfactory for correlation purposes. The inference is that variation in reception appears to be more influenced by surface conditions at the receiving end than at the other points examined along the path.

The data for W2XMN 44.1 Mc comprise a total of 2,112 hours and W2XEA 2,154 hours. Because of the importance of over-the horizon transmission, a percentage distribution with respect to time and decibels has been determined. The authors believe the close comparison of both lower and higher frequencies with atmospheric refraction suggest a common mode of propagation and that refractive bending in the lower atmosphere is a major factor for both frequencies.

Considering other modes of propagation, it would appear that duct transmission should be relatively infrequent for the longer waves of the lower frequency, but if significant on the higher frequency paths, a greater difference would be apparent in the field intensity data gathered. Since both frequencies, however, respond similarly to meteorological changes, there seems to be little evidence from these observations that duct transmission is a dominant factor in tropospheric reception at the frequencies observed unless the assumption of a value of 7 kilometers for a critical duct width at 7 meters is to be questioned.

In the interest of space, plotted values of relative fields in log microvolts/meter are exhibited in weekly means on the accompanying diagram for both W2XMN and W2XEA together with the calculated surface refraction over the interval from August, 1947, to December, 1948.

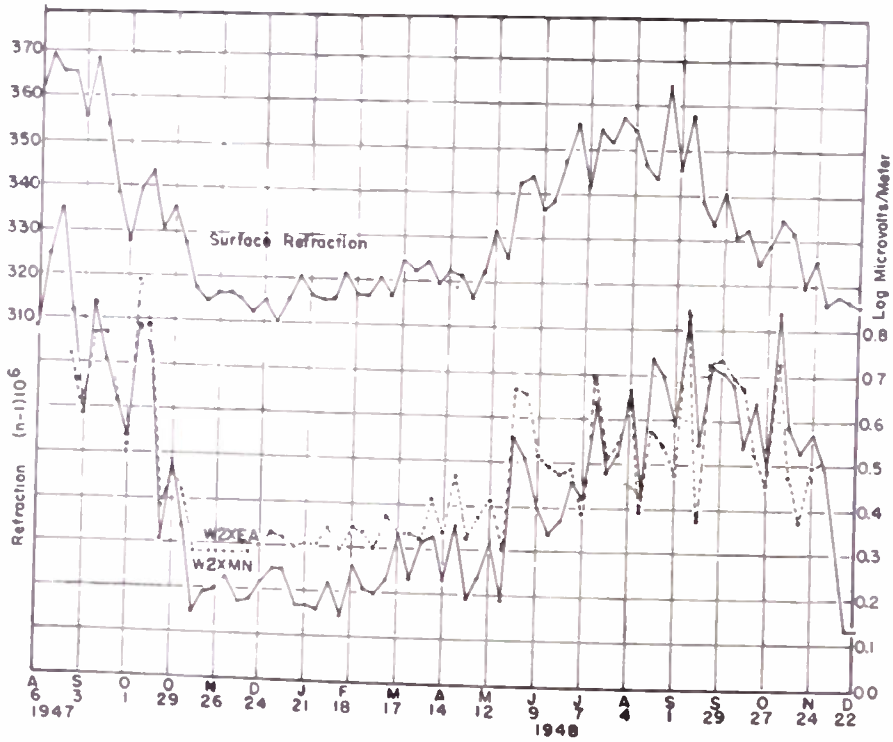


Fig. 1—Weekly means of measured field intensities of W2XMN and W2XEA at Needham Mass. compared with corresponding atmospheric surface refraction at Boston, Mass.

* Decimal classification R112.2. Original manuscript received by the Institute June 7, 1949; abstract received, August 8, 1950.

Abstract based on an extension of a paper originally presented at the International Council of Scientific Unions, Oslo, Norway, August 16–18, 1948.

† Cosmic Terrestrial Research Laboratory, Needham, Mass.

[1] G. W. Pickard and H. T. Stetson, "A study of tropospheric reception at 42.8 Mc and meteorological conditions," Proc. I.R.E., vol. 35, pp. 1445–1451; December, 1947.

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

Russell C. Coile was born in Washington, D. C., on March 11, 1917. He attended the Massachusetts Institute of Technology where he received the S.B. and S.M. degrees in electrical engineering in 1938 and 1939, respectively, as well as the E.E. degree in 1950. While still an undergraduate he served as student engineer with the General Electric Company, was later an engineer's assistant at the Western Electric Company in Kearney, N. J., and, in 1938–1939, was research assistant at the MIT Electrical Engineering Research Laboratories.

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From 1939 to 1942 Mr. Coile held the post of magnetician in the Department of Terrestrial Magnetism at the Carnegie Institution, Washington, D. C. As a reserve officer in the Army Signal Corps, he was called to active duty in World War II, emerging with the rank of major in the Officers Reserve Corps of the Army Air Corps in 1945.

That same year Mr. Coile joined the firm of Colton & Foss, Inc., Washington, D. C., as an electronic engineer. He is now a staff member of the Operations Evaluation Group, Division of Industrial Cooperation, at MIT, a position he has held since 1947.

He is a member of Sigma Xi and Eta Kappa Nu fraternities.

❖

W. Hackett was born in Smethwick, Staffordshire, England. She obtained her technical education at the University of Birmingham, receiving the B.Sc. degree in electrical engineering in 1929 and the Ph.D. degree in 1931.

W. Hackett

As a technical assistant with the British Electrical and Allied Industries Research Association, London, from 1933 to 1944, she was concerned with the development of research and commercial methods of test for dielectric materials and components, and is the author or co-author of a number of papers on the subject. From 1944 to 1946 she was in the employ of A. H. Hunt Ltd., Capacitor Manufacturers, London, engaged on theoretical work and in charge of the test section of the laboratory. Since January, 1947, she has been engaged mainly on circuit analysis with British Telecommunications Research Ltd., Taplow, Bucks., England.

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L. P. Hunter

In 1940 Dr. Hunter joined the Westinghouse Electric Corporation, engaging in work on the physics of solids. His first investigation involved the behavior of the elastic constants during phase changes in solids. During the war he was engaged in microwave magnetron development, and later spent a year at the University of California working on the calutron project. Since the war Dr. Hunter has spent some time in X-ray research. In the summer of 1948 he was a member of the Lexington Evaluation Project of the A.E.C. He has just returned to Westinghouse from a two-year leave at the Oak Ridge National Laboratory, where he was engaged in a study of radiation effects in solids, and is now manager of a section working on solid-state electronics.

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❖

Joseph Manuele was born in Fredonia, N. Y., on November 23, 1897. He was graduated from the Massachusetts Institute of Technology in 1925 with the B.S. degree in electrical engineering, after which he joined the Westinghouse Electric Corporation. Beginning as an inspector of railway equipment, he gained further experience inspecting radio apparatus, power induction regulators, network protectors, and switchboard. In 1930 he was assigned to the headquarters inspection office, and was appointed director of quality control in 1940, his present position.

Joseph Manuele

Previous to his entrance to MIT, Mr. Manuele worked for the United States Radiator Corporation, and the Atlas Crucible Steel Company, where he sampled, stored, and issued various ferro alloys, and eventually became first melter on a six-ton electric furnace. He gave up this position to obtain a high school diploma from Valparaiso University by special examination, after which his credits were accepted by MIT.

Joe Cyril May (S'44–A'46–M'48) was born in McCurtain, Okla. on May 5, 1923. He received the B.S. degree in electrical engineering from Oklahoma Agricultural and Mechanical College in 1944, and the M.E. degree in electrical engineering from Yale University in 1947. He became an instructor in electrical engineering in 1944 and was appointed to the rank of assistant professor in 1949. He has been associated with research on split-anode magnetrons and radar signal-to-noise investigations.

J. C. May

Mr. May is at present Membership Chairman of the Connecticut Valley Section of The Institute of Radio Engineers. He is also a member of the American Institute of Electrical Engineers, Sigma Tau, and Eta Kappa Nu.

❖

Herbert J. Reich (A'26–M'41–SM'43–F'49) was born on Staten Island, N. Y., on October 25, 1900. He received the M.E. degree from Cornell University in 1924, and the Ph.D. degree in physics in 1928. In 1929 he joined the department of electrical engineering at the University of Illinois, where he became assistant professor, associate professor, and professor, successively, of electrical engineering. In January, 1944, he was granted leave of absence to join the staff of the Radio Research Laboratory at Harvard University. In January, 1946, Professor Reich was appointed professor of electrical engineering at Yale University, where he is at present.

Herbert J. Reich

Dr. Reich has specialized in the field of electron tubes and electron-tube circuits, having published numerous papers on these and related subjects in various technical journals. He is the author of "Theory and Applications of Electron Tubes," and "Principles of Electron Tubes," as well as co-author of "Ultra-High-Frequency Techniques."

Dr. Reich is a Director of the IRE, and has served on numerous IRE committees. At present, he is a member of the Board of Editors, the Electron Tube Committee, and the Education Committee of which he is Chairman. He is a member of the American Institute of Electrical Engineers, the American Association for the Advancement of Science, the American Society for Engineering Education, and is a Fellow of the American Physical Society.

Henry E. Singleton (A'47–SM'50) was born on November 27, 1916, at Haslet, Texas. He received the S.M. and S.B. degrees in electrical engineering from the Massachusetts Institute of Technology in 1940. From 1941 to 1946 he worked for the Navy, first with the Naval Ordnance Laboratory and later as a member of the Operations Research Group of the Office of Scientific Research and Development, attached to *Cominch*, U. S. Fleet. After the war he spent two years with the International Telephone and Telegraph Corporation, in New York, N. Y. In 1948 he returned to MIT, where he has been engaged in research on digital computers and nonlinear networks. He is now an instructor in electrical engineering at MIT.

H. E. Singleton

Mr. Singleton received the William Lowell Putnam prize in mathematics in 1939. He is a member of Eta Kappa Nu, and is serving on the Annual Review Committee and the Technical Committee on Modulation Systems of the IRE.

❖

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❖

Norman H. Taylor (SM'50) was born in Manchester, England, on November 15, 1916. He received the B.S. degree from Bates College in 1937 and the S.B. degree in electrical engineering from Massachusetts Institute of Technology in 1939. He received his early training and spent the war years at the Western Electric Company in the Test Equipment Development Engineering Group. Since 1947 he has been at the Servomechanisms Laboratory, MIT, doing research and development on electronic computers. He is at present systems engineer on the Whirlwind digital computer.

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Mr. Taylor is a member of Eta Kappa Nu and Sigma Xi. He is now serving as a member of the Measurements and Instrumentation Committee of the IRE.

❖

Robert L. Ungvary (S'43–A'45–M'50) was born in Stamford, Conn., on April 17, 1921. He received the B.E. degree in electrical engineering in December, 1942, from Yale University. Following a period of war service as a radar officer in the Pacific area, Mr. Ungvary returned to graduate study at Yale, receiving the M.E. degree in June, 1947. He remained at Yale as a research assistant, engaged in classified project work for the Office of Naval Research, until June, 1949. In July, 1949, he joined the engineering staff of the Raytheon Manufacturing Company and is currently engaged in development of airborne radar equipment.

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❖

H. William Welch, Jr., (A'47) was born in Beardstown, Ill., on October 21, 1920. He received the B.A. degree in physics and was elected to Phi Beta Kappa at De Pauw University in 1942. After a summer with the Eastman Kodak Company test laboratories, he spent a year at the University of Wisconsin in graduate study, research, and teaching. In 1943 he went to the Harvard University Radio Research Laboratory as a research associate, where he became involved in magnetron research and development. After spending the first six months of 1946 as a part-time instructor of physics at Purdue University he went to the University of Michigan Engineering Research Institute as a research physicist. He is presently concerned with problems of microwave-tube electronics in the Department of Electrical Engineering Electron Tube Laboratory.

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Mr. Welch received the M.S. degree in physics at the University of Michigan in 1948. He is a member of Sigma Xi and the American Physical Society.

❖

Wilfrid B. Whalley (A'37) was born in Liverpool, England, in 1908. He moved to Canada in 1919. He received the B.A.Sc. degree from the University of Toronto in 1932, following which he was on the staff of the department of electrical engineering for four years and, in 1935, he received the M.A.Sc. degree.

In 1936 Mr. Whalley was a development engineer at the Radio Valve Company in Toronto. From 1937 to 1940 he was with the RCA Manufacturing Company in Harrison, N. J., following which he transferred to war work on radar systems and cathode-ray tubes in Canada. In 1943, Mr. Whalley returned to RCA to engage in research on radar and television transmitting tubes and circuits. He was appointed assistant professor of engineering physics at Cornell University in 1947. At present, he is concerned with television research and development at the physics laboratories of Sylvania Electric Products Inc.

W. B. Whalley

Mr. Whalley is a member of Sigma Xi, American Association of University Professors, and the American Physical Society.

❖

Harold A. Wheeler (A'27–M'28–F'35) was born in St. Paul, Minn., on May 10, 1903. He received the B.S. degree in physics from George Washington University in 1925. From 1925 to 1928 he pursued postgraduate studies in the physics department of The Johns Hopkins University, and lectured there during 1926 and 1927. He was employed as a laboratory assistant in the radio section of the National Bureau of Standards in 1921, leaving in 1923 to assist Professor Hazeltine and later to join the Hazeltine Corporation in 1924. He was in charge of their Bayside laboratory from 1930 to 1937, and advanced to the position of vice-president and chief consulting engineer of Hazeltine Electronics Corporation.

H. A. Wheeler

In 1946 Mr. Wheeler opened his own consulting office in Great Neck, L. I., N. Y. He is now also president of Wheeler Laboratories, Inc., an engineering organization engaged in consultation and the construction of special equipment. Mr. Wheeler is a Fellow of the American Institute of Electrical Engineers and a member of Sigma Xi. He received the Morris Liebmann Memorial Prize in 1940, and was a member of the Board of Directors of the IRE in 1934, and from 1940 to 1945.

Correspondence

Reflected Ray Suppression*

In line-of-sight microwave communications, destructive interference between the direct and the ground-reflected rays may interrupt the service. Although the receiver is sited originally to be in an interference maximum, subsequent atmospheric changes may shift the spatial interference pattern of the source and its image, putting the receiver in a minimum. Diversity reception can be used to alleviate this difficulty. The present note proposes as an alternative remedy that a small screen be set on the ground at the "reflection point" in the path in such a way that the reflected ray at the receiver will disappear almost entirely in theory, and in practice to an extent which depends mostly on the smoothness of the ground plane. The direct wave itself will be only slightly modified. The screen blocks a small part of the reradiation from the ground to the receiver, the design being such that the remainder of the reflected radiation cancels itself to zero at the receiver. Model experiments over an 800-foot transmission path have shown that the scheme is successful.

The foundation for this scheme rests on the fact that the wave field from a point source to a point receiver under free-space conditions becomes zero if part of a Fresnel zone is blocked off in such a way that the remaining diffracted contribution of the zone is unchanged in phase and halved in amplitude. One way to explain the reflection elimination is to use the "method of images." This makes the reflection problem into a free-space transmission problem. The ground plane is removed, there is the source and its image and the screen and its image,[1] and one receiver. To eliminate the image source an opaque quarter-circle whose radius equals the radius of the first Fresnel zone may be erected on the ground. One of the straight edges is on the ground and the other is vertical and exactly centered in the path. The plane of the screen is perpendicular to the path. It is put at the place where the central ray to the image would intersect the ground plane. It may be said that one half of the first Fresnel zone to the image source is blocked by a half-circle; the remaining contribution from this zone is unchanged in phase, and thus the image source is eliminated at the focal point (the receiver). There is a large area around this point where the image is nearly eliminated. It may be noted that a sector of a circle is only one of a large variety of screens which can eliminate a source, or an image source.

In the experiments, a 4,500-Mc transmitter was placed 800 feet from the receiver and 14.3 feet above the ground; the antennas at each end were 4- by 6-inch horns. The receiver could be elevated up and down a 50-foot tower. Numerous tests were made using various shapes and placements of screens. Fig. 1 shows an example of the results obtained. Two triangular screens whose edges were 7.3, 6.6, and 5.4 feet were used for this trial. The figure shows an original recorder tape; time progresses upward on the tape. First, with the path unobstructed, the receiver makes a descent from 4 meters to zero meters (see the height markers on the extreme right). The interference of the reflected ray creates a well-defined pattern. Then the receiver makes an ascent with the two triangular screens eliminating the reflected ray. The correct position for the screens moves along the path as the receiver elevates, therefore the ascent was stopped every half-meter in order to reset the screens. The influence of the reflected wave is mostly eliminated at the receiver and the remaining direct wave has the correct strength, 6 decibels weaker than in the former interference maxima.

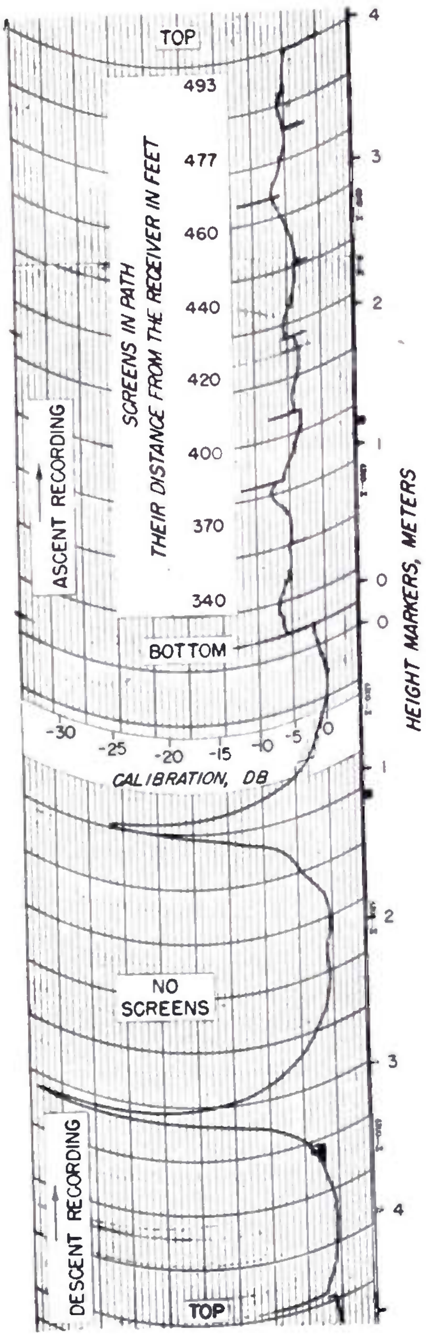

Fig. 1—Signal-strength-versus-height record showing reflected wave suppression. Height markers on right; zero mark is about 7 feet above the ground. (The break in the record marks an equipment difficulty.)

The experiments confirm the theory and indicate that trouble with a strong reflected wave can be eliminated by erecting small screens in the path, or when possible by taking advantage of an obstacle already present. In many cases it may be sufficient to reduce the apparent reflection coefficient to the order of six or seven tenths in order to render the reflected wave rather harmless; and to accomplish this much reduction only a very small screen is needed.

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* Received by the Institute, March 30, 1950.

[1] The use of an image screen in this explanation was suggested by my colleague, J. H. Chisholm.

A Note on the Synthesis of Resistor-Capacitor Networks*

In their paper on the synthesis of R-C lattice networks,[1] Professors Bower and Ordung present a method for realizing maximum gain in a prescribed voltage transfer ratio. The method, in the case when the load is negligible, consists of placing one of the roots of an arbitrary polynomial $F_1(p)$ so that one of the equality signs in

$$-1 \leq \frac{hk_\nu^{(n)}}{k_\nu^{(d)}} \leq 1 \qquad (10)$$

holds at the largest minimum of the prescribed transfer ratio $|A(p)|$ plotted for negative real p.[2] The remainder of the roots of $F_1(p)$ are then placed arbitrarily within prescribed intervals.

By careful placement of the remainder of the roots of $F_1(p)$, it is possible to achieve a design having a maximum gain factor *with a minimum number of elements*. Such a design is obtained by making one or the other of the equality signs in (10) hold at *each* of the roots of $F_1(p)$. This can always be done, once h has been chosen for maximum gain or less. The result is that Z_a and Z_b (see (7) and (9)) each have different poles, the total number n being equal to the degree of $F_1(p)$. Thus the degenerate lattice designed on this basis will contain n capacitors, rather than the $2n-1$ which result when the remainder of the roots is placed arbitrarily. Since h is generally chosen on the basis of the maximum gain requirement alone, and since

* Received by the Institute, May 1, 1950.

[1] J. L. Bower and P. F. Ordung, "The synthesis of resistor-capacitor networks," Proc. I.R.E., vol. 38, p. 263; March, 1950.

[2] All equation numbers refer to the aforementioned paper.

$$\frac{hk_\nu^{(n)}}{k_\nu^{(d)}} = hA\Big|_{p=\gamma_\nu},$$

it is evident that all of the roots of $F_1(p)$ should be placed at points in their prescribed intervals where $|A| = 1/h$. In some intervals, there is an optional choice between two such values of p.

As an example of the method, consider the transfer ratio

$$A = \frac{p^2 + 42p + 3600}{(p+5)(p+300)}.$$

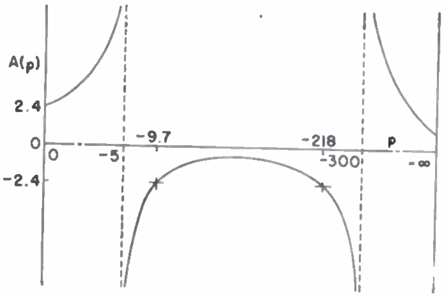

Fig. 1—$A(p)$ for example of unloaded lattice.

A plot of $A(p)$ is shown in Fig. 1. It is evident that for maximum gain, $h = 1/2.4$ and the critical root of $F_1(p)$ is at $p = 0$. The other root of $F_1(p)$ can be placed at $p = -9.7$ or $p = -218$ where $|A| = 2.4 = 1/h$. Both values should be tried in order to achieve the most reasonable spread of element values. For the larger value

$$F_1(p) = p(p+218).$$

One then obtains

$$Z_a - Z_b = \frac{1}{2.4}\cdot\frac{p^2+42p+3600}{p(p+218)}$$

$$= \frac{1}{2.4}\left[1 + \frac{16.5}{p} - \frac{192}{p+218}\right]$$

$$Z_a + Z_b = \frac{(p+5)(p+300)}{p(p+218)}$$

$$= 1 + \frac{6.87}{p} + \frac{80.2}{p+218},$$

from which

$$Z_a = 0.708 + \frac{6.87}{p}$$

$$Z_b = 0.292 + \frac{80.2}{p+218}.$$

The resulting lattice is shown in Fig. 2.

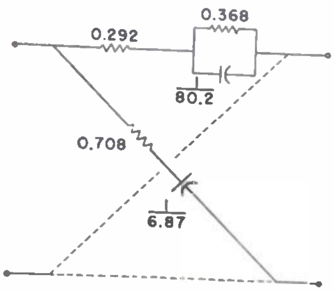

Fig. 2—Lattice network, $F_1(p) = p(p+218)$.

This lattice is easily reduced to three-terminal form, and the final network (Fig. 3) contains only two capacitors.

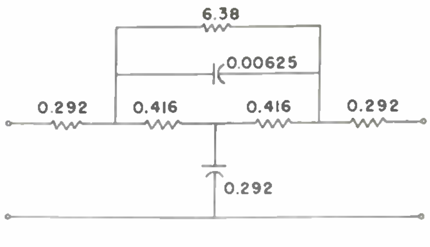

Fig. 3—Reduced network, $F_1(p) = p(p+218)$.

For $F_1(p) = p(p+9.7)$ one obtains

$$Z_a = 0.708 + \frac{155}{p}$$

$$Z_b = 0.292 + \frac{141}{p+9.7}.$$

The final reduced network is shown in Fig. 4.

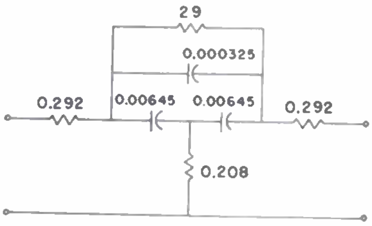

Fig. 4—Reduced network, $F_1(p) = p(p+9.7)$.

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Relation of Nyquist Diagram to Pole-Zero Plots in the Complex Frequency Plane*

Although the relation of the familiar Nyquist diagram to pole-zero plots is undoubtedly well known to those whose daily work takes them on frequent excursions into the complex frequency plane, it is neither immediately obvious nor commonly mentioned.

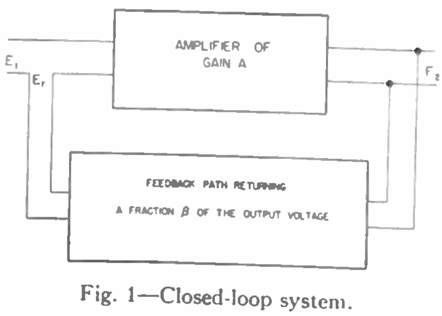

Fig. 1—Closed-loop system.

The closed-loop system of Fig. 1 has a gain, with feedback, of $A/1 - A\beta$. The Nyquist criterion for stability states that the system is stable if a polar plot of $A\beta$ does not enclose the point (1, 0). On the other hand, the system is known to be stable if the complex gain E_2/E_1 does not have a pole in the right half of the complex frequency plane $p = \sigma + j\omega$. In other words, stability is insured if the amplifier with feedback does not give infinite gain to signals of the form $Ee^{\sigma t}e^{j\omega t}$ for any positive value of σ. The equivalence of these two statements is easily shown by an example.

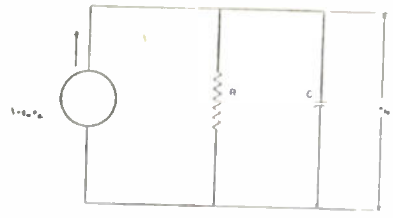

Fig. 2—High-frequency equivalent circuit of resistance-coupled amplifier stage.

Consider an amplifier made up of four identical resistance-coupled stages each having the equivalent circuit of Fig. 2. Let the feedback network be a simple resistance voltage divider so that β is a (negative) constant fraction. The gain of the amplifier, and also the gain around the closed loop

$$A\beta = \beta\,\frac{A \text{ midband}}{(1+pRC)^4}$$

have fourth order poles at $p = -(1/RC)$ (Fig. 3). Contours of constant magnitude of

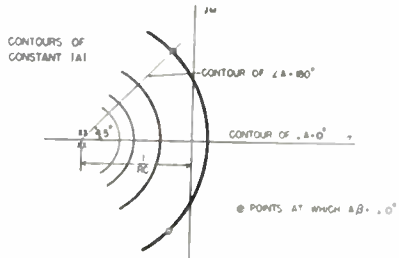

Fig. 3—Pole-zero plot of loop gain $A\beta$.

$A\beta$ are concentric circles about the point $p = -(1/RC)$; contours of constant phase shift around the closed loop are radial lines. At the two points indicated in Fig. 3 the magnitude of $A\beta$ is assumed to be unity and the phase shift of A is 45° per stage or a total phase shift in the amplifier of 180°.

Consider now the overall gain with feedback, $A/1 - A\beta$. It will have poles for the values of p for which $A\beta = 1$. The system is stable if these poles all fall in the left half of the complex frequency plane; unstable if any fall in the right half plane. (Fig. 4.)

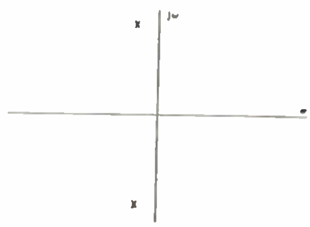

Fig. 4.—Poles of over-all gain (with feedback) $A/1 - A\beta$ corresponding to points $A\beta = 1$ in Fig. 3.

It remains to relate these plots to the Nyquist plot of loop gain $A\beta$ of Fig. 5. This is a simple matter—the gain is a rational function of the complex frequency p and the Nyquist plot of Fig. 5 is a conformal mapping of the positive $(j\omega)$ axis of Fig. 4. The first quadrant of the complex frequency plane maps into the shaded area of Fig. 5. Thus the

* Received by the Institute, June 12, 1950.

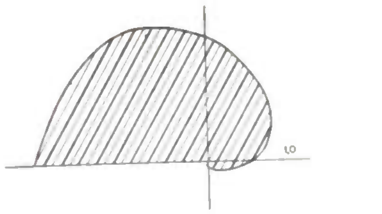

Fig. 5—Nyquist polar plot of $A\beta$.

statements for a stable system that the point (1, 0) must lie outside the Nyquist plot, and that the over-all gain must have no poles in the right half of the complex frequency plane are completely equivalent.

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Elliptically Polarized Waves*

In the paper "Antennas for Circular Polarization," by Sichak and Milazzo,[1] an expression is derived for the voltage induced in an arbitrarily elliptically polarized receiving antenna by an elliptically polarized wave. The derivation is based on the fact that the elliptically polarized waves may be assumed to be made up of two linearly polarized components. This expression is equation (2) of the above paper.

$$V = K\left[1 \mp \frac{2r_2r_1}{(r_2^2+1)(r_1^2+1)} + \frac{(r_2^2-1)(r_1^2-1)}{(r_2^2+1)(r_1^2+1)}\cos 2\alpha\right|^{1/2}, \quad (1)$$

where K is a constant, r_1 is the axial ratio of the receiving antenna, r_2 is the axial ratio of the transmitting antenna, and α is the angle between the major axes of the two ellipses of polarization. The $(-)$ sign is used if the senses of rotation of the two antennas are opposite and the $(+)$ sign is used if the senses are the same.

An alternate method of approach, and one which is perhaps simpler and more physically apparent, is to assume that an elliptically polarized wave is made up of two circularly polarized components of opposite sense of rotation, and of the proper relative phase and magnitude. The sense of rotation of the resultant wave is the same as the sense of the larger component. Then

$$r_1 = \left|\frac{R_1+L_1}{R_1-L_1}\right|, \qquad r_2 = \left|\frac{R_2+L_2}{R_2-L_2}\right|, \quad (2)$$

where R_1, L_1, R_2, L_2, are the right- and left-handed amplitude components of the receiving and transmitting antennas, respectively. Also

$$\frac{R_1}{L_1} = \frac{r_1+1}{r_1-1} \text{ for right-handed waves,}$$

$$= \frac{r_1-1}{r_1+1} \text{ for left-handed waves, and}$$

$$\frac{R_2}{L_2} = \frac{r_2+1}{r_2-1} \text{ for right-handed waves,}$$

$$= \frac{r_2-1}{r_2+1} \text{ for left-handed waves.} \quad (3)$$

If the major axes of the ellipses of polarization of the transmitting and receiving antennas are at angles γ and β, respectively, then the resultant fields may be represented as

$$E_2 = R_2 e^{j(2\tau-2\gamma)} + L_2$$
$$E_1 = R_1 + L_1 e^{j(2\tau-2\beta)}. \quad (4)$$

The voltage induced at the receiver terminals of an antenna, compared to that which would be induced if both antennas were correctly linearly or circularly polarized, is

$$\frac{V_R}{V_0} = \left| R_2R_1 e^{j(2\tau-2\gamma)} + L_2L_1 e^{j(2\tau-2\beta)}\right|$$
$$= \left| R_2R_1 e^{j2\alpha} + L_2L_1\right| \quad (5)$$

Where $\alpha=\beta-\gamma$. Expanding,

$$\frac{V_R}{V_0} = [R_1^2R_2^2 + L_1^2L_2^2 + 2R_1R_2L_1L_2\cos 2\alpha]^{1/2} \quad (6)$$

Usually it is more convenient to express (6) in terms of the axial ratios. Using the relations (3) and realizing that $R^2+L^2=1$, (normalizing the power in the wave), we may substitute in (6) and get for the power received relative to the maximum power

$$\frac{P_R}{P_0} = \left(\frac{V_R}{V_0}\right)^2$$
$$= \frac{(1+r_2)^2(1\pm r_1)^2 + (1-r_2)^2(1\mp r_1)^2}{4(1+r_2^2)(1+r_1^2)}$$
$$+ \frac{(1+r_2)(1-r_2)(1+r_1)(1-r_1)}{2(1+r_2^2)(1+r_1^2)}\cos 2\alpha$$
$$= \frac{1}{2} \pm \frac{2r_1r_2}{(1+r_1^2)(1+r_2^2)}$$
$$+ \frac{(1-r_1^2)(1-r_2^2)}{2(1+r_1^2)(1+r_2^2)}\cos 2\alpha. \quad (7)$$

The $(+)$ sign is used when the two antennas have the same sense of rotation and the $(-)$ when the sense of rotation is opposite. This result (7) is the same as Sichak and Milazzo's (1). This is made obvious by squaring both sides of the latter expression, and dividing both sides by $2K^2$, since $P_0 = 2K^2$.

This derivation has as an interesting and useful by-product, equation (6). This latter form may be conveniently used for many cases, particularly where it is easier to deal with right- and left-handed components, rather than axial ratios. For instance, consider two antennas linearly polarized in the same direction. Here $R_1=R_2=L_1=L_2=0.707$ and $\alpha=0$. Therefore $V_R/V_0=[0.25+0.25+0.50]^{1/2}=1$. If on the other hand the two antennas are orthogonal, $\alpha=90°$, and $V_R/V_0=0$. Similarly if two right-handed circularly polarized antennas are used $R_1=R_2=1$, $L_1=L_2=0$ and $V_R/V_0=1$, as is also the case for two left-handed antennas. If, however, one left- and one right-handed antenna are used, $R_1=L_2=0$, and $R_2=L_1=1$, or $R_1=L_2=1$ and $R_2=L_1=0$, and $V_R/V_0=0$.

The case for optimum power transfer is readily determined from (6) or (7). The conditions are $\alpha=0$, and either the polarization parameters $R_1=R_2$ and $L_1=L_2$ in (6), or the sense of rotation of the two antennas is the same and $r_1=r_2$ in (7).

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* Received by the Institute, May 21, 1950.
[1] W. Sichak and S. Milazzo, "Antenna for circular polarization," PROC. I.R.E., vol. 36, pp. 997–1002; August, 1948.

An Achromatic Microwave Antenna*

Several years ago the writers were interested in the design of an achromatic microwave antenna for wide angle scanning. The use of constrained transmission through a metal plate lens seemed promising because thereby Abbe's sine condition can be satisfied and the design is simpler than for nonconstrained transmission. It is recognized that Abbe's sine condition is only an approximate requirement and that, therefore, the angle of scan attainable with this lens probably will not approach that recently disclosed in the literature.[1] The achromatic feature should, however, be interesting.

Figs. 1 and 2 show two such antennas

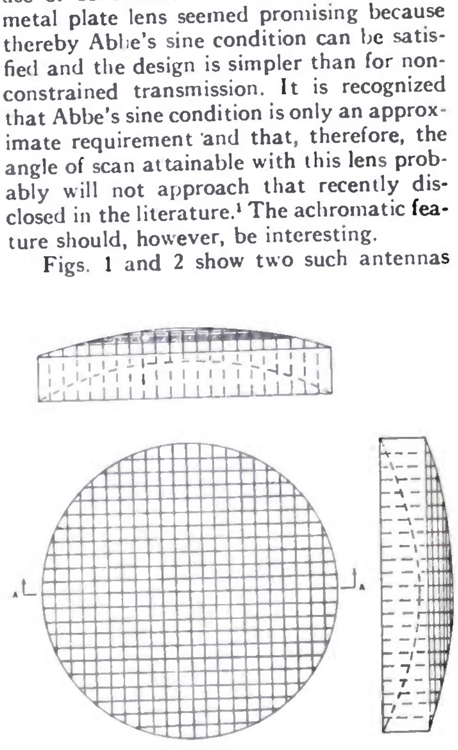

Fig. 1—Lens antenna for pencil-shaped beam.

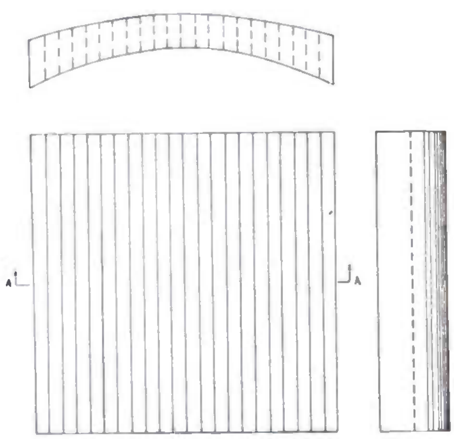

Fig. 2—Lens antenna for fan-shaped beam.

having, respectively, a pencil-shaped and a fan-shaped beam. Note that the first is doubly constrained. Fig. 3 shows a section AA through either antenna perpendicular to the metal plates. The electric field is polarized to be perpendicular to this section. Surface (X_1, Y) is a sphere or cylinder whose center is at F and whose radius is a. In order to satisfy Abbe's sine condition for minimum coma, the antenna feed is located at F (i.e., the focal length is a). A phase shift invariant with frequency, but varying from point to point such that the spherical aberration vanishes, is assumed to exist at surface (X_1, Y). This

* Received by the Institute, May 25, 1950.
[1] J. Ruze, "Wide-angle metal-plate optics," PROC. I.R.E., vol. 38, pp. 53–59; January, 1950.

condition can be approximated by properly modifying this ideal surface to eliminate the spherical aberration, and by utilizing steps to bring the modified surface back to the vicinity of the ideal surface, wherever the deviation becomes excessive. Surface (X, Y) is chosen to minimize the chromatic aberration.

The dotted line represents the path of a ray going from F to (X_1, Y) to (X, Y) to a plane perpendicular to and cutting the axis at the vertex of the surface (X, Y).

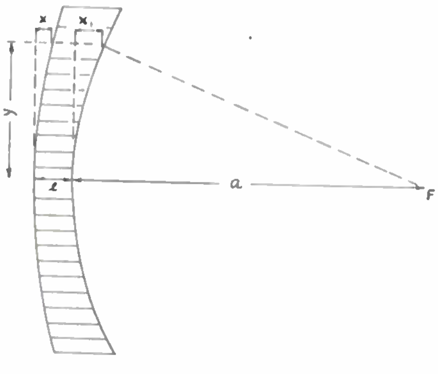

Fig. 3—Cross section (AA) through either antenna.

In order that the lens shall be achromatic, the difference measured in wavelengths, between the dotted and the axial paths, should not change with frequency. While this can not be done exactly, it can be accomplished for two frequencies. If these two frequencies are located near the edges of the frequency band in which the lens is to operate, the lens can be made approximately achromatic over the whole band. That is,

$$\phi(y) + \frac{a+x}{\lambda_1} + \frac{x_1+l-x}{\lambda_{g_1}} - \phi(0) - \frac{a}{\lambda_1} - \frac{l}{\lambda_{g_1}} = \phi(y) + \frac{a+x}{\lambda_2} + \frac{x_1+l-x}{\lambda_{g_2}} - \phi(0) - \frac{a}{\lambda_2} - \frac{l}{\lambda_{g_2}} \qquad (1)$$

where

$\phi(y)$ is the surface phase shift at points (X_1, Y) or (X, Y)

$\phi(o)$ is the surface phase shift at point (0, 0)

λ_1 is the free-space wavelength corresponding to one frequency

λ_2 is the free-space wavelength corresponding to the other frequency

λ_{g_1} is the wavelength in the lens at λ_1

λ_{g_2} is the wavelength in the lens at λ_2.

Collecting terms, (1) can be written

$$x = \frac{x_1}{1 - \dfrac{1/\lambda_1 - 1/\lambda_2}{1/\lambda_{g_1} - 1/\lambda_{g_2}}}$$

or

$$x = \frac{x_1}{1 - \dfrac{f_1 - f_2}{n_1 f_1 - n_2 f_2}} \qquad (2)$$

where n_1 and n_2, the indices of refraction, correspond to the frequencies f_1 and f_2, which in turn correspond to λ_1 and λ_2 respectively.

This is the equation of the desired curve. It will be noted that when double constraint is employed, the phase or stepping correction can be applied to either surface (X_1, Y) or (X, Y).

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Stratospheric-Ionospheric Relationships*

An attempt has been made to determine whether any correlation existed between pressures and temperatures, as found at the tropopause or in the lower stratosphere, and electron densities found in the several ionospheric regions. The original impetus for this investigation arose from the various reported correlations between surface meteorological factors and ionospheric parameters. On the whole, previous studies[1-13] had attempted a direct correlation generally between the barometric pressure at the earth's surface and critical frequencies of the ionospheric layers. However, as surface pressure is highly dependent upon the mass of relatively shallow air masses (of depth mainly less than 3–4 km in the case of polar air) which in many instances rarely affect higher level meteorological conditions, a new datum level for the study was adopted.

There does not seem to be a one-to-one correspondence between barometric pressure variations at the ground and, for example, those at the tropopause. In the atmosphere, high-frequency wave components (cyclone waves) are found which generally do not extend to 9–11 km. In other cases, however, it is not known with certainty whether or not the high-frequency components do extend to the tropopause. In any event, it would seem that those atmospheric disturbances which affect the stratosphere may also be present in sufficient strength to affect the ionized regions also. A correlation might then be attempted between meteorological parameters in the stratosphere (where the magnitude of the high-frequency wave components, found at the surface, is reduced) and ionospheric conditions in the various ionized layers.

An investigation of this type was made between ionospheric layer critical frequency and (a) temperature and pressure at the tropopause and (b) temperature and pressure at an altitude of 13 km. In undertaking the study, radiosonde and ionospheric data for Washington, D. C., were examined for the period January 1, 1946, to December 31, 1947. The criterion adopted for the definition of "tropopause" was that advocated by Flohn and Penndorf.[14] Thus a tropopause was considered to be that point above which the lapse rate first falls below 2°K/km providing this or a lesser lapse rate continues through an altitude range of 1.5 km or more. Instances where no well defined tropopause existed were not included in the analysis. Ionospheric data were obtained from the CRPL[15] series. Only the critical frequency of the ordinary ray was considered. As radiosonde data are available only at 0430 Greenwich Mean Time and 1630 GMT, only two sets of data per day could be employed.

The investigations reveal no correlation between either the temperature or pressure at the tropopause and the critical frequency of any of the ionospheric regions. Also, no correlation was evident between temperatures at 13 km and the critical frequency of the ionospheric layers.

Considering the pressure at 13 km and the critical frequency at the E and F_2 regions, some slight correlation was found in several instances. However, no correspondence was found with sporadic E conditions. Results of the examination are given below in Table I.

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TABLE I

Correlation Between Pressure at 13 km and Critical Frequency

Ionospheric Region	*Correlation Coefficient*	*Probable Error of Correlation Coefficient*	*Standard Deviation of Critical Frequency (Mc/s)*	*Standard Deviation of Pressure (mb)*
E layer, daylight	0.53	0.05	0.27	6.4
F_2 layer, daylight	−0.37	0.04	2.22	6.1
F_2 layer, darkness	0.45	0.05	1.20	5.9

Appreciation is expressed to Miss A. M. Walter for her careful assistance in performing the computations.

[1] C. G. Abbott, "Correlation of Solar Variation with Washington Weather," *Smithsonian Misc. Collection*, vol. 104, pp. 1–10; 1945.

[2] J. Bannon, A. J. Higgs, D. F. Martyn, and G. H. Munroe, "The association of meteorological changes with variation of ionization in the F_1 region of the ionosphere," *Proc. Roy. Soc.*, vol. A174, pp. 289–309; 1940.

[3] J. Bannon, A. J. Higgs, and G. H. Munroe, "Magnetic disturbances and region F_1 of the ionosphere," *Terr. Mag.*, vol. 46, pp. 61–70; March, 1941.

[4] U. A. Baranulko, "Temperature of the upper layers of the atmosphere," *Priroda*, vol. 34; May, 1948.

[5] J. E. Bost, F. T. Farmer, and J. A. Ratcliffe, "Studies of region E of the ionosphere," *Proc. Roy. Soc.*, vol. A164, pp. 96–116; February, 1938.

[6] R. C. Colwell, "Atmospheric conditions and the Kennelly-Heaviside layer," *Nature*, vol. 130, pp. 627–628; October, 1932.

[7] R. C. Colwell, "Cyclones, anticyclones, and the Kennelly-Heaviside layer," Proc. I.R.E., vol. 21, pp. 721–725; May, 1933.

[8] R. C. Colwell, "Effect of thunderstorms upon the ionosphere," *Nature*, vol. 133, p. 948; June, 1934.

[9] E. Gherzi, "Ionospheric reflections and weather forecasting for eastern China," *Bull. Amer. Met. Soc.*, vol. 27, pp. 114–116; March, 1946.

[10] V. N. Kessenikh and H. D. Bulatov, "The continental effect in the geographic distribution of the electron concentration in the F_1 layer," *Compt. Rend. Acad. Sci.* (URSS), vol. 45, pp. 234–237; Nov., 1944.

[11] D. F. Martyn, "Atmospheric pressure and the ionization of the Kennelly-Heaviside layer," *Nature*, vol. 133, pp. 294–295; February, 1934.

[12] T. G. Mihran, "A note on a new ionospheric-meteorological correlation," Proc. I.R.E., vol. 36, pp. 1093–1096; September, 1948.

[13] I. Ranzi, "Causes of ionization in the upper atmosphere," *Nature*, vol. 130, p. 545; October, 1932

[14] H. Flohn and R. Penndorf, "The stratification of the atmosphere, I," *Bull. Amer. Met. Soc.*, vol. 31, pp. 71–78; 1950.

[15] CRPL Series F., "Ionospheric Data," CRPL, Washington, D. C.; 1945–1947.

Institute News and Radio Notes

Color Television Discussed at Electronics Conference

Chairman Wayne Coy of the Federal Communications Commission gave the reasons back of the recent decisions regarding color television in speaking at the opening luncheon of the 1950 National Electronic Conference held on September 24–27, at the Edgewater Beach Hotel, Chicago, Ill.

Total registration at the conference was 2,350, well above the figure for the 1949 conference. Some 60 exhibitors occupied all of the space used in previous conferences, and overflowed into the main corridor of the hotel.

"Twenty-Five Years of Progress," was the theme. Many exhibits, including old as well as new equipment, were shown. The exhibit of the IRE Chicago Section was presented in connection with its Silver Anniversary Celebration.

All of the eighteen technical sessions during the conference were well attended. *Proceedings* of the Conference will be published early in 1951. Most of the 60 technical papers presented have already gone to the editors. The volume may be ordered from the National Electronics Conference, Inc., 852 E. 83 St., Chicago 19, Ill.

Speakers at the meeting included Titus Le Clair, national president of the AIEE, who introduced E. A. McFaul, formerly of Northwestern University, who spoke on the subject, "Is The Engineer Slipping?"

The major social event was the Old Timers Dinner in the hotel ballroom at which the IRE Chicago Section was host to many outstanding figures in the electronics industry who had been active and prominent in the field for twenty-five years or more. W. L. Everitt, Dean of Engineering, University of Illinois, introduced the honored guests.

The sponsor of the Wednesday luncheon was The Institute of Radio Engineers. Raymond F. Guy, IRE president and manager of radio and allocation engineering of the National Broadcasting Company, introduced John V. L. Hogan, who spoke on the subject, "What's Behind IRE?" Mr. Hogan prominent inventor in the radio and electronics field, was one of the organization's founders. He recounted its early history and outlined plans for the future.

The 1951 National Electronics Conference is scheduled for October 22, 23, and 24 and will be held at the Edgewater Beach Hotel, Chicago, Ill.

Discuss Color Television
From left to right: Nathan Cohn, President of NEC and Wayne Coy, FCC Chairman at National Electronics Conference.

Peter Mole Is Elected New President of SMPTE Group

Peter Mole, president of the Mole-Richardson Co., Hollywood, Calif., was elected president of the Society of Motion Picture and Television Engineers at a meeting of the Board of Governors which preceded the opening of the organization's 68th semiannual convention at Lake Placid.

Others who will assume office on January 1 are: Herbert Barnett, General Precision Laboratories, Pleasantville, N. Y., as executive vice-president; and John G. Frayne of the Westrex Corp., Hollywood, Calif., as editorial vice-president. Re-elected to office were William C. Kunzmann as convention vice-president and Robert M. Corbin as secretary.

Other officers of The SMPTE include Fred T. Bowditch, engineering vice-president; Ralph B. Austrian, financial vice-president; and Frank Cahill, treasurer.

The new Board of Governors of the SMPTE who will take office on January 1, include: William B. Lodge, CBS; Oscar F. Neu, Neumade Products Co.; Frank E. Carlson, GE, Nela Park; Malcolm G. Townsley, Bell and Howell; Thomas T. Moulton, 20th Century Fox, Hollywood; Norwood L. Simmons, Eastman Kodak; and Lloyd Thompson, Calvin Co.

> **IRE/AIEE/RDB**
> **Joint Conference on Electron Tubes for Computers**
> **Haddon Hall Hotel**
> **Atlantic City, New Jersey**
> **December 11 and 12, 1950**
>
> Monday, December 11
>
> 9:30 A.M. Computer Experience with Electron Tubes.
> 1:30 P.M. Electron Tube Problems.
> 8:00 P.M. Special Purpose Computer Tubes.
>
> Tuesday, December 12
>
> 9:00 A.M. Tube Manufacture and Crystal Diode Experience.
> 1:00 P.M. Williams-Type Storage.

Monmouth Subsection Sponsors Program of Community Service

The Monmouth Subsection of the New York Section of The Institute of Radio Engineers is sponsoring a number of interesting projects as a part of its Community Service program for the year 1950–1951. Included in its program are the following activities: professional assistance in civil defense planning and operating; reconditioning of donated television and radio receiving sets for installation in hospitals and welfare agencies for the use of patients and inmates; courses for laymen in popular electrical subjects, such as "Electricity in the Home," as a part of existing adult education programs; participation in the career counseling program of high schools and junior colleges, featuring vocational guidance in the field of radio electronics; liaison with other professional groups, such as doctors and lawyers, in matters of general interest to the community and of mutual interest to two or more professions; and newspaper columns or articles on the popular aspects of television and related subjects of general interest.

Included on the local IRE Community Service Committee are G. L. Van Deusen of RCA Institute; S. D. Robertson and L. E. Hunt, Bell Telephone Laboratories; H. S. Bennett, Watson Laboratories; John L. Slattery and A. Enurian, Evans Signal Laboratories; George Trad and J. D. Winer.

> **NOTICE**
>
> **Effective January 1, 1951, the Student dues will be $5.00 per year. Payments at the old rate of $3.00 will be accepted through December 31, 1950. All payments received thereafter will be at the new rate.**

25 Years of IRE in Canada

1925—Canadian IRE Section Formed

The IRE was introduced to Canadian radio engineers on October 2, 1925, in Toronto, when a Canadian Section was organized by C. L. Richardson, the first Chairman, who was elected along with Dugald Hepburn, Vice-Chairman, W. J. Hevey, Secretary, C. C. Meredith, Assistant Secretary, and G. F. Eaton, Treasurer. From this beginning with some 53 members and guests present, IRE in Canada has grown constantly until there are now 958 Fellows and members of all grades. Sections and Subsections have been formed in six additional cities, and student branches at the Universities of Alberta and Toronto. Much credit for the advancement of IRE in Canada goes to Ralph A. Hackbusch, Fellow, 1937, who was Chairman of the Toronto Section, 1932–1933; Director, 1938; Vice-President, 1944; Director-At-Large, 1945 and 1946

C. L. Richardson
Chairman, Canadian Section
1925 1926

1950—Present Canadian Council IRE

R. G. Anthes
Education

C. A. Norris
Vice Chairman and Membership

F. S. Howes (F'50)
Past Chairman

F. H. R. Pounsett (F'47)
Regional Director
Chairman Canadian Council
1949–1950

R. C. Poulter
Professional Status

G. J. Irwin
Regional Convention

❖

A. H. Sievert
Publicity

The Canadian Council of the IRE was formed in 1945 to co-ordinate the activities of the various Canadian Sections in National matters. This plan formed the basis of the organization now in effect in the eight IRE regions. Despite the obstacles of distance, the Canadian Council has performed its function well.

J. C. R. Punchard
Secretary

❖

C. G. Lloyd
Papers and Silver Anniversary

Present Canadian Council IRE (cont'd.)

T. I. Millen
Chairman, 1950–1951

C. G. Lloyd
Chairman, 1949–1950

TORONTO SECTION, 1925

J. C. Bernier
Chairman, 1950–1951

A. B. Oxley
Chairman, 1949–1950

MONTREAL SECTION, 1937

The Montreal section was organized by a group which had previously helped to organize the Canadian (now Toronto) Section twelve years earlier. A. M. Patience was the first Chairman.

B. R. Tupper
Chairman, 1950–1951

A. H. Gregory, Chairman,
Organizing Committee

VANCOUVER SECTION, 1950

The newest Canadian section has just been formed under the organizing hand of A. H. Gregory and the Chairmanship of B. R. Tupper. This fills a long expressed need for IRE on Canada's west coast.

J. T. Henderson
Chairman, 1950–1951

A. W. Y. Desbrisay
Chairman, 1949–1950

OTTAWA SECTION, 1944

Engineers and scientists in the Armed Forces Headquarters and the National Research Council formed the Ottawa IRE section, with F. P. Park as acting Chairman, followed by Col. W. A. Steele.

S. G. L. Horner
Chairman, 1950–1951

R. D. Cahoon
Chairman, 1949–1950

WINNIPEG SUBSECTION, 1945

Formed as a subsection of the Toronto Section under W. A. Cole as chairman, this group now plans to apply for full Section status. This is an indication of its growth and activity in the years since its formation.

F. P. Kehoe
Chairman, 1950–1951

G. W. Foster
Chairman, 1949–1950

LONDON, ONT. SECTION, 1944

With Professor G. A. Woonton as the Chairman, the first London Section meeting achieved distinction by viewing its charter on a local television hook-up. From this beginning, it too has constantly grown.

L. R. Harris
Chairman, 1950–1951

A. H. Sievert
Chairman, 1949–1950

HAMILTON SUBSECTION, 1947

Also a subsection of the Toronto section, this group was formed under the Chairmanship of T. S. Farley. It was then and has continued since as one of the most active IRE groups in Canada.

Technical Committee Notes

The Standards Committee, under the Chairmanship of J. G. Brainerd, held a meeting on September 14, 1950, at which reports on the activities of the various Subcommittees of the Standards Committee were given by their respective Chairmen. The Technical **Committee on Nuclear Science has been disbanded** in view of the fact that work previously done by this Committee is now handled by the IRE Professional Group on Nuclear Science. . . . **The Video Techniques Committee held a meeting** on October 2, 1950, J. E. Keister, Chairman, presiding. . . . **R. L. Garman, of Subcommittee 23.2** Utilization; Including Video Recording, has prepared a paper on "Video Utilization; An Introduction and Definition of the Art" for publication in the PROCEEDINGS. H. J. Schlafy, another member of this Subcommittee, is the author of a paper which will also be published in PROCEEDINGS OF THE I.R.E., entitled, "Comparative Factors of Picture Resolution in Television and Film Industries." A proposed Standards on Television: Methods of Measurement of Electronically Regulated Power Supplies, prepared by the Video Techniques Committee has been approved by the Standards Committee. Chairman Keister reported on the Joint IRE Committee for Television. The letters IRS stand for IRE, RTMA and SMPTE. The Committee's Chairman is A. G. Jensen of the Bell Telephone Laboratories. The IRE members of this Committee are M. W. Baldwin, Jr., and R. L. Garman. . . . **A meeting of the Circuits Committee** was held on September 15, W. N. Tuttle, Chairman, presiding. Comprehensive reports of the activities of the Subcommittees of the Circuits Committee were given by the respective Chairmen. . . .

Please note that the **Conference on Electron Tubes for Computers** previously scheduled to be held in Washington, D. C., **will be held** in Haddon Hall **on December 11–12, 1950,** Atlantic City, N. J. . . . A meeting of the **Antennas and Waveguides Committee** was held on September 12, under the Chairmanship of A. G. Fox. . . . Work is progressing towards the **publication of the revision of the present IRE Master Index of Terms. . . . The IRE will participate in the Annual Convention of the Institute of Aeronautical Sciences** which will be held in New York, N. Y., the last week in January, 1951. . . . A **joint IRE/IAS Committee** is organizing a full-day program of approximately eight papers to be devoted to "Electronics in Aviation." As soon as details for this event are formulated they will be announced. . . . **The Navigation Aids Committee held** a meeting on September 22, under the Chairmanship of P. C. Sandretto. . . . **The Joint Technical Advisory Committee, under** the Chairmanship of J. V. L. Hogan, held a meeting on September 14. The JTAC has prepared a supplementary statement which was submitted to the Federal Communications Commission in October. . . . E. K. Gannett, Technical Editor of PROCEEDINGS OF THE I.R.E., **has been appointed to serve as IRE Representative on the Subcommittee on Abbreviations of the ASA Sectional Committee Z10.**

IRE Board of Directors Announces 1951 Awards

The Board of Directors of The Institute of Radio Engineers, upon the recommendation of the Awards Committee, has named the recipients of the annual awards for 1951. Presentation of the awards will be made by the President at the annual banquet, a feature of the 1951 IRE National Convention to be held on March 19–22 at the Waldorf-Astoria Hotel and Grand Central Palace in New York, N. Y.

The awards will be presented to the following: Medal of Honor, V. K. Zworykin; Morris Liebmann Memorial Prize, R. B. Dome; Browder J. Thompson Prize, A. B. MacNee; Harry Diamond Memorial Award, M. J. E. Golay; Editor's Award, W. W. Harman.

Fellows, highest membership grade in IRE, will also be announced at that time.

Calendar of COMING EVENTS

IRE-AIEE Conference on Electron Tubes for Computers, Atlantic City, N. J., December 11–12

AAAS Annual Meeting, Cleveland, Ohio, December 26–30

AIEE-IRE-NBS High Frequency Measurements Conference, Hotel Statler, Washington, D. C., January 10–12

AIEE Winter General Meeting, Hotel Statler, New York, N. Y. January 22–26

1951 IRE National Convention, Waldorf-Astoria Hotel and Grand Central Palace, New York, N. Y., March 19–22

IRE Southwestern Conference, Dallas, Texas, April 20–21, 1951

1951 Annual Meeting of the Engineering Institute of Canada, Mount Royal Hotel, Montreal, May 9–11

1951 IRE Technical Conference on Airborne Electronics, Biltmore Hotel, Dayton, Ohio, May 23–25

1951 IRE West Coast Convention, San Francisco, Calif., August 29–31

Bell System Will Expand Its Television Network Channels

The Long Lines Department of the American Telephone and Telegraph Company made a 50 per cent increase on September 30 in the number of cities connected in its television networks.

This expansion, the largest since the eastern and midwestern TV networks were joined in January, 1949, will add 14 cities to the present 28-city networks and, for the first time, carry live network television as far south as Jacksonville, Fla., and as far west as Omaha, Neb.

The route extensions will give network service to 19 more television stations covering areas populated by about 12 million people. The present Bell System network serves 54 stations in areas populated by about 60 million people, according to estimates in the industry. Latest estimates indicate that on September 30 better than 80 per cent of the nation's seven and one-half million television sets will be in range of live network broadcasts.

Five of the new network cities are in the southeast: Greensboro and Charlotte, N. C.; Jacksonville; Atlanta, Ga.; and Birmingham, Ala. Two are in the central area: Indianapolis, Ind. and Louisville, Ky.; and seven in the west central area, including Rock Island, Ill., Davenport and Ames, Ia., Omaha, Kansas City, Mo., and Minneapolis and St. Paul, Minn.

IRE Vancouver Section Formed; Toronto Celebrates 25th Year

At its September meeting the Board of Directors approved the establishment of the new Vancouver Section, as the fifty-seventh IRE Section, to include the Provinces of Saskatchewan, Alberta, British Columbia, and the Yukon Territory. The addition of the Vancouver Section brings to a total of five the number of Sections in Canada.

The territory comprising the Vancouver Section was relinquished by the Toronto Section, which this month is celebrating the Silver Anniversary of its founding as the first IRE Section in Canada and one of the first seven Sections established by the Institute.

Western Union Company Has Developed Amplifier Cable

The Western Union Telegraph Company has recently revealed the development of the world's first submerged transatlantic cable amplifier. As the result of the invention the annual capacity of Western Union's cable system will be increased by more than one hundred million words and will have far-reaching effects in greatly reducing the frequency demands in the crowded global radio spectrum. The first amplifier will be inserted in a transatlantic cable 1,800 feet down, at the bottom of the ocean, northeast of Newfoundland in July, and at least double the speed of that cable.

The 3-stage amplifier, developed under the direction of H. P. Corwith (M'26–SM'43), vice-president of Development and Research, will be equipped with three complete sets of vacuum tubes. An electrically operated switch, controlled from a shore station, will change tubes in the event of tube failure.

While in recent years a few submerged telephone repeaters have been laid in short cable, this is the first amplifier developed for the cables now spanning the Atlantic.

Industrial Engineering Notes[1]

Television News

Color Television Inc., has petitioned the FCC for a "reopening of the record" and for a further "hearing" on color TV matters. CTI told the FCC it has "invented a wholly new method of transmitting and receiving signals capable of producing television pictures in full color." "This new method," CTI said, "is unique and is believed to be superior to any other color television system heretofore suggested to the Commission in connection with the development and promulgation of standards" for commercial color television. Labelled "uniplex," the new system was said to be fully compatible with present black-and-white television. Detail is transmitted in all colors, CTI said, with the resolution "corresponding with black and white." CTI said the "uniplex" receiver circuit requirements are no more critical than for black-and-white reception. It will accurately reproduce monochrome transmission, the petition said, and CTI receivers using the new system will function with any presently disclosed direct-view color tube, requiring fewer additional receiving tubes over black-and-white sets than any color TV system so far proposed, and without loss of fidelity. Conversion of standard black-and-white sets to color, CTI said, is practical through the use of a small and inexpensive unit plus a direct-view color tube. This small unit was not described. CTI stated that it would require about three dates to present testimony on the new system. . . . Television receiver production reached a new peak of 702,287 sets in August, bringing the industry total for eight months to 4,146,602 TV sets in August, according to RTMA industry estimates. The industry's output through August was 1.1 million units higher than for the entire year, 1949. . . . Radio set production was estimated at 1,203,447 units in August and 8,750,965 during the eight-month period. The August report both for radio and TV covers only four weeks, or through August 25. RTMA estimates are for both members and nonmembers.

Radio and Television News Abroad

The Netherlands plans to inaugurate television service for the public early next year, according to information received by the U. S. Department of Commerce. Present plans call for the establishment of six transmitters the first of which is to be located at Lopik to serve The Hague, Amsterdam, and Rotterdam areas. The Dutch transmission will utilize 625 lines. . . . The market in Honduras for radios, tubes, and parts, although small, is increasing, the Department of Commerce has reported. In the fiscal year ended June 30, 1949, the value of imports of radio equipment was $240,907, compared with $182,471 in the corresponding period of 1948. . . Annual production of radio sets in Uruguay is estimated at 35,000 to 40,000 units, according to a report to the U. S. Department of Commerce. Many of the components used in radio assembly are of U. S. origin, although variable condensers, as well as speakers and transformers, are now produced locally. The trend in the industry, is, however, toward self-sufficiency in all major components except capacitors and resistors. The United States' share of the market for radios declined from 76 per cent in 1948 to 34 per cent in 1949, while the share of Great Britain increased from 11 per cent to 40 per cent. Holland and Denmark accounted for 19 per cent of the imports in 1949. The United States' share of the radio parts market declined from 85 per cent in 1948 to 57 per cent in 1949, while Great Britain's proportion increased from 4 to 33 per cent. These shifts are attributed to the dollar shortage, and do not reflect any lack of demand for United States products, the Commerce Department said.

Munition Board Announces Security Procedure Check

The Munitions Board has established uniform policies, procedures, and standards to aid industry in clearing facilities and personnel to handle classified matter in dealing with the Army, Navy, or Air Force on military contracts.

Regulations covering the uniform procedure have been issued to the armed services. A central security file has been established to maintain data on all individuals, organizations, facilities, factories, etc., that have been cleared by the military departments.

The new regulations are designed to eliminate past duplications necessitated by requiring plants to fill out forms for some bureaus in the Navy, another for the Air Force, and still another for the Army. Now one form only will be required for all.

Statistics

A record production of television receivers was set in August by the radio-television manufacturing industry, according to estimates projected from RTMA member-company production reports. RTMA estimates show a total of 702,287 TV receivers manufactured by the industry during a four-week period ending August 25. Radio set production was also at high level with 1,203,447 being produced during the month. During the fourth week 187,891 TV sets are estimated by RTMA to have been manufactured. . . . Rectangular TV picture tubes accounted for 47 per cent of the July cathode-ray tube sales to set manufacturers, according to member company reports to RTMA. Due to the vacation shutdown of manufacturing plants, July sales of cathode-ray tubes of 16 inches and larger in size, picture tubes 15 inches and less accounted for only 15 per cent of the July sales, while tubes 19 inches and larger amounted to slightly more than 11 per cent.

Committees Agree on 50 Microvolts as Goal in FM Radiation Reduction

Members of the R6 Committee on FM Receivers and the R15 Committee on Radio Interference, Receiver Section, of the RTMA Engineering Department, on Tuesday, September 12, adopted a resolution recommending that by June 30, 1951, all FM receivers in production comply with a radiation limitation of 50 microvolts per meter at 100 feet.

The committee also adopted a resolution recommending that standards also be adopted, following appropriate early study, for television receivers and radiation limits were suggested of 50 microvolts per meter at 100 feet on channels 2 through 6, and 150 microvolts per meter at 100 feet on channels 7 through 13.

Curtis Plummer, FCC Chief Engineer, while not committing the Commission to the acceptance of any value, commended the industry for the progress that has been made by the committees and urged the immediate adoption of the recommended standard in the production of FM sets.

Earlier the industry engineers brought out the lack of uniform standards for measuring radiation, and it was agreed that FCC engineers will co-operate with industry engineers in tests to be made in Philadelphia, Chicago, and Washington. An IRE committee is working on standards for such measurements.

New FM Service Requested by Multiplex Corporation

The Multiplex Development Corporation petitioned the FCC to change its rules governing FM broadcasting to permit "multicasting" by FM stations. The company has been conducting developmental broadcasts and experiments since June 5 under a Commission developmental license. The plan would permit FM stations to utilize their frequencies for a "supplementary" broadcast service. The company claims this is possible without interference occurring to other FM broadcasts.

Public service uses of the new method were cited, including use of "multicasting" by civil defense authorities. The proposed method would also provide a service for transit radio and storecasting, the petition said.

States Cannot Censor Television Films

The Third United States Court of Appeals has held that state boards of censors have no right to censor motion-picture films to be used on television programs. The unanimous ruling stated that Congress, and not the individual states, can regulate television broadcasts.

Record Factory Lay-Offs in July

The U. S. Department of Labor has reported that the lay-off rate in July in the nations' factories declined to 6 per 1,000 employees, the lowest level in four years. The stepped-up rate of hiring which was reached in June was maintained in July, the Department said. Factories hired workers at a rate of 46 for every 1,000 employees on the payroll.

[1] The data on which these NOTES are based were selected by permission from *Industry Reports*, issues of September 1, September 8, September 15, September 29, published by the Radio-Television Manufacturers Association, whose helpful attitude is gladly acknowledged.

IRE People

Kahn Re-elected President of Radio Parts Meeting

Jerome J. Kahn, president of Standard Transformer Corp., was re-elected president of the Radio Parts and Electronic Equipment Shows, Inc., at the annual meeting at the Greenbrier Hotel, White Sulphur Springs, W. Va.

Samuel J. Spector, of Insuline Corp. of American, was chosen vice-president; Lew Howard, Triad Transformer Mfg. Co., secretary; and Charles A. Hansen of Jensen Mfg. Co., treasurer.

The board of directors voted to hold a three-day show May 21, 22, and 23 at the Hotel Stevens, Chicago, Ill., with booths in Exhibition Hall and display rooms on the fifth and sixth floors open from 10:30 to 6 P.M. daily.

Accelerate Crystal Processing

The Signal Corps has begun an expedited crystal processing program because of the urgent requirements caused by the current international situation it has been announced. Approximately four million crystals will be processed within the next ninety days, with the work load equally distributed between the New Cumberland General Depot, Pa., and the Decatur Signal Depot, Ill.

United States Plans to Purchase Radios for Possible Use Abroad

The Department of State has revealed that discussions have been held with four radio manufacturers on the purchase of 200,000 small radios for possible use behind the Russian "iron curtain." The plan is aimed at increasing the number of listeners to the Voice of America program.

A supplemental appropriations bill now before Congress contains $2,860,000 in funds for the purchase of such sets in addition to $41,288,000 for new VOA transmitting stations.

Manufacturers interested in the project, according to the State Department, are RCA International; General Electric International; Pilot Radio Corp.; and Emerson Radio and Phonograph Corp. The first three concerns are understood to have submitted models, and Emerson was said to have made a price quotation.

The type of set needed to cover the standard broadcast band and all the international bands up through 22 Mc. Discussions so far have involved battery-operated sets.

Top Government Officials Reassure NAB on Its Plans

Two important Government officials, FFC Chairman Wayne Coy and John Steelman, assistant to the President, have assured the nation's broadcasters through the National Association of Broadcasters that there were no plans presently contemplated to restrict their activities during the current emergency.

Dr. Steelman emphasized that American radio and television broadcasters could expect no controls beyond those self-imposed ones that were employed during the war.

R. G. E. Hutter (SM'46), head of the electronics research section of the Physics Laboratory, Sylvania Electric Products Inc., Bayside, L. I., N. Y., has been appointed adjunct professor at the Brooklyn Polytechnic Institute, where he will conduct classes in electron tube theory and electron optics.

R. G. E. Hutter

A native of Berlin, Germany, Dr. Hutter was a graduate student in physics and mathematics at the University of Berlin from 1930 to 1936. From 1936 to 1938 he served as a research physicist in the Telefunken transmitter laboratories, and in 1938 and 1939 was chief engineer of station KZIB in Manila, P. I. During 1940 and 1941 he was a graduate student in communication engineering and physics at Stanford University serving, until he received the Ph.D. degree in 1944, as a research associate in the University's Division of Electron Optics.

Since then Dr. Hutter has been associated with the Physics Laboratories of Sylvania Electric. He is also a member of the American Physical Society and Sigma Xi.

His course in electron tube theory will include an analysis of the basic operating conditions for microwaves.

Merle A. Tuve (F'45), of the Carnegie Institution, Washington, D. C., has been awarded a Howard N. Potts Medal by the Franklin Institute for the proximity fuze which helped attain many decisive victories in World War II.

The citation accompanying the award reads: "In recognition of the scientific insight exhibited in the conception of the TV Proximity Fuse and of the administrative ability and practical good judgment shown in the supervision of its development and engineering design."

Dr. Tuve was born in Canton S. D. He was graduated from the University of Minnesota as an electrical engineer in 1922 and received the M.A. degree the following year. In 1926 Johns Hopkins awarded him the Ph.D., and honorary D.Sc. degrees were given him by Case, Kenyon, and Williams Colleges in 1948 and 1949. Before joining the staff at Carnegie Institution in 1926, he was physics instructor both at Princeton University and at Johns Hopkins.

Among the honors held by Dr Tuve are: Commander, Order of the British Empire; the AAAS prize in 1931; Presidential Medal for Merit, 1946; The Research Corporation award, 1947; the John Scott award, Philadelphia; and the Comstock Prize of the National Academy. He is a Fellow of the American Physical Society, and a member of the American Philosophical Society, National Academy of Sciences, American Academy of Arts and Sciences, American Geophysical Union, Phi Beta Kappa, Tau Beta Pi, and Sigma Xi.

Dr. Tuve is editor of the *Journal of Geophysical Research* and contributes papers to the *Physical Review* and other scientific journals regarding nuclear physics, geophysics, and biophysics. At present he is doing research relative to the crust of the earth and its early geological history.

John E. Allen (A'23–SM'45), chief of tests for the Pennsylvania Water and Power Company and the Safe Harbor Water Corporation, and known nationally for his contribution to the progress of electrical engineering, died in August at Lancaster, Pa. Mr. Allen, who was 57 years old, had been ill for about three months.

He was best known for his work in developing the high-frequency fault locator. He was a joint recipient in 1935 of a first prize award by the Edison Electric Institute for this work. Another of his inventions was a high-speed frequency indicating meter which permitted instantaneous perception of alternating-current frequency.

Among his other research accomplishments were contributions to the reduction of the effects of lightning on transmission lines; the improvement of governors for hydro turbines; the measurement of radio field strength preliminary to the design of a space radio system; and the design and construction of equipment for carrier current and land wire telephone systems.

He was also a member of the AIEE in which organization he was a Fellow, and was a member of the National Association of Corrosion Engineers, the Instrument Society of America, and the American Association for the Advancement of Science.

John T. Wilner (A'37–M'46–SM'48), engineering director of radio stations WBAL and WBAL-TV, has been elected vice-president in charge of engineering of Hearst Radio, Inc. He formerly was engineer-in-charge of CBS television development.

Mr. Wilner is one of the country's foremost authorities on television transmission techniques. He is the inventor and designer of numerous video circuit refinements, including an electronic horizontal wipe.

IRE People

O. W. Pike (A'26–M'29–SM'43–F'51), manager of engineering in the tube divisions of General Electric Co.'s electronics department, died on October 7 at Ellis Hospital in Schenectady, N. Y. He was 51 years old. Mr. Pike became associated with General Electric Company in 1920.

O. W. PIKE

Mr. Pike, who was graduated from the University of New Hampshire with the B.S. degree in electrical engineering, joined the company as a student engineer. In 1922 he was transferred to the research laboratory to do developing work on small transmitting tubes. He was placed in charge of development of low power tubes in 1924, and later on assumed responsibility for the development of gas and mercury vapor tubes.

Mr. Pike was appointed designing engineer when the vacuum-tube department was formed in 1930. He was then placed in charge of the design and development of both industrial and radio tubes, and when the tube division was created in 1943 he was then named division engineer.

He was chairman of the Joint Electronic Tube Engineering Council when it was formed and continued as a member until his death.

He was named to receive the 1950 Radio Fall Meeting Plaque to have been given during the meeting on October 30–November 1, for his work in organizing JETEC.

⁂

I. J. Melman (A'43) has been appointed head of the advanced development division of Air King Products Co., Inc., manufacturers of radios, wire recorders, and television receivers. He will be in charge of advanced development as well as television research for Air King.

Mr. Melman formerly was associated with Micamold Radio Corporation, and was senior instructor at the Air Forces Communications School at Scott Field and Yale University. From January, 1945, until his present appointment he was a member of the technical staff of the RCA Industry Service Laboratories.

Dundas P. Tucker, Captain, U. S. Navy (A'36–SM'46) has been appointed Director of the Navy Electronics Laboratory, located on Point Loma near San Diego, Calif. This Laboratory is responsible for a large portion of the research and development work of the Navy Bureau of Ships in radio, radar, acoustics, and allied fields. His previous assignment was Director of the Electronic Design and Development Division, Navy Bureau of Ships.

Captain Tucker's electronics activities cover a span of more than thirty years. He received the B.S. degree from the U. S. Naval Academy in 1925, and the M.A. degree from Harvard University in 1934.

During World War II Captain Tucker was responsible for the radar and guided missiles program of the Navy Bureau of Ordnance. He was the originator of the Navy's "Bat," the first automatic guided missile to see regular service use. He was awarded the Legion of Merit for these war services.

⁂

Hector R. Skifter (A'31–M'36–SM'43), president of Airborne Instruments Laboratories, Inc., Mineola, L. I., N. Y., has been appointed chairman of the Committee on Navigation of the Department of Defense Research and Development. **Norman L. Winter** (A'47–M'47), assistant to the vice-president and general sales manager, Sperry Gyroscope Co., Great Neck, L. I., N. Y., has been appointed a member of the committee.

Dr. Skifter, who has been a member and vice-chairman of the committee since its formation in June, 1948, has been serving as acting chairman for the past six months. During World War I he was associate director, Airborne Instruments Laboratory of Columbia University, Division of Research.

Dr. Winter has been associated with the Research and Development Board since its formation, serving as executive director of its Committee on Electronics from its formation in August, 1946, until May, 1949, and as a consultant since then. He served as a colonel in the Air Force during World War II and his last position was as Chief, Plans Section, Electronic Subdivision, Engineering Division, Air Materiel Command. He has been with Sperry Gyroscope since he left the Committee on Electronics.

Donald G. Fink (A'35–SM'45–F'47) is another member of the committee, while **W. J. Merchant** (SM'47) is executive director of the Committee Secretariat which carries on the work of the part-time committee.

⁂

Vladimir K. Zworykin (M'30–F'48) has been awarded the 1950 Progress Medal of the Society of Motion Picture and Television Engineers, the highest honor granted by the Society for significant scientific contributions in a new field. His basic research and developments have helped make television a present-day reality.

Dr. Zworykin received the award at the 68th semiannual convention of the SMPTE at Lake Placid, N. Y. He is vice-president and technical consultant of the RCA Laboratories Division, Radio Corporation of America.

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John H. Howard (SM'50) has been named a member of the staff of the Research Division of the Burroughs Adding Machine Company in Philadelphia, Pa. Until recently he had been a consultant in the field of electronic control systems.

JOHN H. HOWARD

Mr. Howard, who holds the B.S. degree in electrical engineering from Kansas State College, received an appointment in 1935 as a research associate at the Massachusetts Institute of Technology, where he received the M.S. degree in electrical engineering in 1939.

After completing three years of service with the U. S. Navy in 1946, he was Director of Development at Engineering Research Associates and was later associated with the Sperry Gyroscope Company.

He is also a member of the AIEE, Sigma Xi, and Phi Kappa Phi.

⁂

Charles E. Apgar, a pioneer radio operator, died recently at his home at Westfield, N. J., at the age of 85 years. During the first World War Mr. Agpar aided the United States government in detecting subversive messages from a German radio station located at Sayville, L. I., N. Y. He recorded code messages from the station which was said to be broadcasting information to German submarines on the movements of neutral ships, and caused the government to seize the station.

Mr. Apgar, who was born in Gladstone, N. J., attended Wesleyan University. He was associated with the New York Life Insurance Company, and was a salesman before he became an executive for the New York brokerage firm of Spencer Trask and Company. His hobby was astronomy and he wrote for the publication of the Royal Canadian Astronomical Society, and other periodicals.

Mr. Apgar joined The Institute of Radio Engineers as an associate in 1913, but later resigned his membership.

IRE People

Norman E. Wunderlich (M'49) has been elected vice-president and general manager of the Link Radio Corporation, N. Y., and will be in charge of all company activities. **Frederick T. Budelman** (A'41) has been named vice-president in charge of engineering and research, and as assistant to Mr. Wunderlich.

Since last July Mr. Wunderlich has been associated with Link Radio Corp., in the establishment of a Chicago office and service center, and in organizing a sales-engineering force throughout the Middle West.

He has been active in the radio and electronic industry for over 30 years. Previously, he had been connected with the administrative, executive, and engineering management of Motorola, IT&T Corp., and Federal Telephone Radio Corp., and was a co-owner of the Rauland Corp., director of engineering and research for the Victor Talking Machine Co. and RCA Victor Co., vice-president of Lear, Inc., and founder and owner of Wunderlich Radio Corp.

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Sam Norris (A'47) has been elected president of the Amperex Electronic Corp., Brooklyn, N. Y. Previously, he had been executive vice-president.

He has been closely associated with the growth of Amperex, which for over twenty years has been a leading manufacturer of power and transmitting tubes and is a pioneer in the ultra-high-frequency field. Its newest developments include a new-type rotating anode X-ray tube, geiger counters, magnetrons, and power tubes.

Mr. Norris was graduated from Cornell University with the B.A. degree in 1927.

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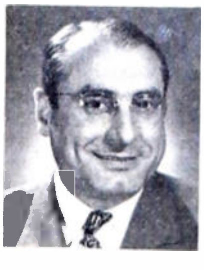
John H. Ganzenhuber (A'42), formerly manager of broadcast sales for Western Electric Co., has been appointed vice-president in charge of the sales and product development of Standard Electronics Corp., wholly owned subsidiary of Claude Neon, Inc. He will supervise Standard's national sales program and be responsible for equipment development. His work will have particular emphasis on the television broadcast field.



J. H. Ganzenhuber

In addition to handling Western Electric's broadcast sales operations, Mr. Ganzenhuber took an active part in Western Electric's radar program for the Armed Forces during the war. Prior to this he was field sales engineer and district manager of broadcasting sales for Graybar Electric Co. for nine years. This latter organization will distribute Standard Electronics' entire line of television, AM, and FM broadcast equipment.

Mr. Ganzenhuber, who was born on September 19, 1909, was graduated from the University of Southern California in 1933 with the B.S. E. E degree

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Adriano A. Pascucci (SM'48), director of the research laboratories, Radio Hispano Suiza, Barcelona, Spain, has been awarded, together with H. W. Stawski, the first "Bosone's Prize" at the annual general Board of Directors' meeting of the Associazione Elettrotecnia Italiana in Milano, Italy, in April. The award will be given annually by the Associazione Elettrotecnia Italiana for outstanding achievements in the field of experimental research on dielectrics.

Dr. Pascucci's and Dr. Stawski's contributions to the knowledge of dielectric properties of ceramic materials include development and experimental tests on ceramic titanates, and a system of frequency modulator realized with a titanate nonlinear capacitor, presented in October, 1947, at the international congress for the celebration of the 50th anniversary of Marconi's discovery of radio, which was held in Rome, Italy, from September 28 to October 5.

In 1948 Dr. Pascucci joined the Radio Hispano-Suiza as research director, where he is now engaged in Industrial Television research. He is also a member of the Acoustical Society of America, the American Institute of Physics, and the Associazione Elettrotecnica Italiana.

❖

William R. Spittal (A'40), former general manager and vice-president of Ferranti Electric Inc., New York, N. Y., recently opened a new plant, known as the Highland Engineering Co., 32 Holman Blvd., Hicksville, N. Y., for the manufacture of transformers, inductors, rectifiers, power supplies, and the like for industrial and electronic fields.

Mr. Spittal is a graduate of the University of Toronto, receiving the B.A.Sc. degree in 1927 and the electrical engineering degree in 1933.

❖

William S. Dawson (A'49), formerly with Headquarters, Airways and Air Communications Service, Washington, D. C., has arrived in Tokyo for assignment to Headquarters, 1808th AACS Wing. He has been assigned duties as Weather Communications Advisor in his new organization.

He will make frequent field trips all over the Far East area, "trouble shooting" weather communications facilities. In Washington Major Dawson was Facsimile Project Officer for the AACS.

G. F. Callahan (A'39) has been appointed to a supervisory position in General Electric's cathode-ray tube division. A native of Elk Point, S. D., he was graduated from the University of Nebraska in 1924 with the B.S. degree in electrical engineering.

G. F. Callahan

In 1931 he joined the Ken-Rad Tube and Lamp Corporation at Owensboro, Ky., where he worked on the design of receiving tubes and served for four years as the Works Manager of the Bowling Green plant. Prior to that he had been engaged in the design, development, and manufacture of lamps and electronic tubes for several manufacturing concerns.

When GE acquired the Ken-Rad tube business, Callahan became active in the development of new miniature and cathode-ray receiving tubes. In 1948 he was appointed division engineer of the cathode ray tube division with headquarters in Schenectady. When the cathode-ray tube plant was built in Syracuse, he moved to Electronics Park in the same capacity as division engineer.

❖

Milton A. Chaffee (M'49), field supervisor for Airborne Instruments Laboratory, Mineola, L. I., N. Y., who as an electronic expert was assigned by the U. S. Air Force to the Berlin Airlift to help establish its famous record in 1949, has been sent to the Far East to aid the USAF.

Mr. Chaffee has been with the Airborne Instruments Laboratory since 1945. Formerly he was associated with the Radiation Laboratory at MIT for three years. He is a graduate of the University of California, where he also did graduate work.

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New appointments at Bendix Radio Division, Bendix Aviation Corporation of Baltimore, Md., include that of **R. B. Moon** (A'42) who has been named assistant general sales manager. **J. W. Hammond** (A'39–SM'45) has been transferred to the Friez Instrument Division of Bendix Aviation Corp. as director of sales, and **R. L. Daniel** (M'46) will continue as manager of aviation radio sales, the company has announced.

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S. M. Decker (A'45) has been appointed assistant chief engineer of the Television Department of Air King Products Co., Inc., Brooklyn, N. Y., manufacturers of radios, wire recorders, and television receivers. Mr. Decker has been a prominent member of the radio field since 1939, and formerly was assistant chief engineer at Garod Radio Corp.

Books

Ionization Chambers and Counters by D. H. Wilkinson

Published (1950) by Cambridge University Press, 51 Madison Ave., New York 10, N. Y. 255 pages+6-page index+ix pages. 79 figures. 5½×8½. $4.50.

The advanced reader in the growing literature of nuclear science has available relatively few specialized books on the instruments of the field. Since the war many engineers have interested themselves in Geiger counters and ion chambers; thus this new book on the subject of these instruments will probably be eagerly sought, the more so because there are so few books of its type and because nuclear instrumentation is undergoing rapid development so that books in the field age quickly.

Engineers will not find Wilkinson's book aimed in their direction. Basically, the approach is one of developing the principles of Geiger counters and ion chambers. Much attention is given discussions which have a highly analytic texture so that the engineer will find he has to brush up on his physics to follow the arguments. The mathematics are quite straightforward and should present no difficulty. In spite of the theoretical nature of many pages in the book and the involved intricacies of the Geiger counter mechanisms, the reader will find that considerable technology has been woven into the treatment. This is most welcome especially as the author tends to strip away from Geiger counters the mystic ritual which so long attended their construction.

Professor Wilkinson has focused his treatment upon the principles of instrumentation, particularly upon the Geiger counter and ion chamber, to the exclusion of any description of the crystal counter and some of the more recent nuclear detection devices. None the less, the book is very complete and well organized with respect to the more conventional counting devices.

R. E. Lapp
Nuclear Science Service
Washington, D. C.

New Publications

"Bibliography of Electron Microscopy," by C. Marton, S. Sass, M. Swerdlow, A. Van Bronkhorst, and H. Meryman, (87 pages, 25 cents a copy) is available from the Superintendent of Documents, U. S. Government Printing Office, Washington, 25, D. C. Remittances from foreign countries should be in United States exchange and should include an additional sum of one-third of the publication price to cover mailing costs.

The titles of the publications have been grouped in the following broad categories: Books, survey articles, instrumentation, electron optics, related instruments, and applications. Within each group the arrangement is chronological, and within each year it is alphabetical by author.

Each reference is consecutively numbered, and a special author index refers to these numbers. Only those papers having a direct bearing on electron microscopy and published before January 1, 1950, have been included. Semiscientific, popular accounts, and patent literature have been omitted.

Heaviside's Electric Circuit Theory by H. J. Josephs

Published (1950) by John Wiley and Sons, Inc., 440 Fourth Ave., New York 16, N. Y. 113 pages+2-page index+viii pages. 15 figures. 4×6½. $1.25.

This book, one of the series of Methuen Monographs on Physical Subjects, although small physically (it will literally fit easily in the coat pocket) contains a worthwhile amount of material having to do with the methods introduced by Heaviside for solving the differential equations of electric circuits. It is by now becoming possible to take a reasonably dispassionate view of the field of the operational calculus without hindrance from the violent controversies that raged over it in its early days.

Such a view leads one to the conclusions that Heaviside was unquestionably a genius, that he and pure mathematicians simply did not approach compatibility, and that his unorthodox and sometimes intuitive methods led to striking results and probably goaded the pure mathematicians on in directions they might not otherwise have travelled, with the result that today Heaviside's procedures may be justified by processes of adequate mathematical rigor.

It then becomes a matter of preference as to whether the present-day workers stay with Heaviside's formalism, taking on all the risks of trying to follow a genius in his thought processes, or uses the more humdrum procedure on the Laplace transform and associated complex variable theory. The reviewer must confess a preference for the latter approach, and with it the possibility of bias.

The book is based on a series of out-of-hours lectures delivered to engineers of the Post Office Research Station. It begins with a review of the classical solution of the differential equations in terms of given boundary values. From there Heaviside's expansion method is introduced and applied to various cases. A theorem only recently discovered among Heaviside's papers is then demonstrated and used to obtain many further results. Apparently Heaviside himself did not use the theorem in this way.

The theorem itself is by now a well-known one, having been rediscovered at various times. What was not so well known was the fact that Heaviside had been thinking along such lines. The book closes with a chapter outlining the connections between the Heaviside operational approach and the modern mathematical procedures.

One minor objection that may be raised concerns the practice of writing the operational equation as an equation with an ordinary equality sign. Either a special symbol or a functional notation would seem to offer less possibility of confusion and would have ample precedent. Such criticism should not however be allowed to hide the fact that the book fulfills its avowed aim in a most commendable manner.

S. N. Van Voorhis
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Atomic Physics by Wolfgang Finkelnburg

Published (1950) by McGraw-Hill Book Co. 330 W. 42 St. New York 18, N. Y. 475 pages+17-page index+x pages. 226 figures. 9¼×6¼. $6.50.

This book attempts to present a connected account of the present state of our knowledge of the structure of matter from elementary particles up to the latest concepts of the solid state, at a level suitable for seniors and graduate students in science or engineering. The author has stressed the meaning of experiments and theories, and the interrelations between such seemingly divergent fields as atomic, molecular, nuclear and solid-state physics, without plunging the reader into a morass of mathematical or experimental details.

Following two chapters in which the groundwork for the discussion is developed with the introduction of the fundamental notions of atomic theory and of the elementary particles, Professor Finkelnburg gives an unusually readable account of the development of spectroscopy and the Bohr theory. In Chapter 4 he introduces quantum mechanics, pointing out just where the Bohr theory proved inadequate, and where the quantum theory scored its greatest successes. The final section of this chapter deals with the achievements, limitations and philosophical significance of quantum mechanics. The fifth chapter (98 pages) is devoted to nuclear physics, and the final two chapters are concerned with molecular physics and atomic physics of the liquid and solid state.

Each chapter is provided with an extensive bibliography, but specific references to original papers and mathematical derivations are generally lacking. While these omissions would seriously impair the value of the book as a text or reference work, they do make it more readable. In the opinion of this reviewer the book should be an excellent one for an engineer or scientist who wishes to bring himself up to date on the whole subject of modern physical thinking. In this respect I believe it fills a long-felt want.

The book appears to be unusually free of errors or misprints and only occasionally was I conscious of the fact that it is a translation from the German. The author has taken great pains to bring his material up to the minute and should be congratulated on a splendid job.

J. B. Horner Kuper
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Upton, L. I., N. Y.

Primary Batteries by George Wood Vinal

Published (1950) by John Wiley and Sons, Inc., 440 Fourth Ave., New York 16, N. Y. 329 pages+6-page index+xi pages. 101 figures. 5½×8½. $5.00.

This is a new book, on a subject which has for long been in need of comprehensive treatment such as is incorporated in the twelve extended chapters of this work. In our recollection it is the only thorough treatment of primary batteries in many years covering history, theory, materials, chemical reactions, manufacture and operating characteristics of standard cells, copper and copper oxide cells, silver oxide and chloride batteries, lead cells having soluble reaction products, mercury oxide and vanadium dry cells, and fuzed-electrolyte cells.

There are authoritative chapters on the operating characteristics of dry cells, and the effect of low temperature on dry cells and low-temperature types. Some primary batteries have been developed that are capable of discharge at high rates comparable with or surpassing those of storage batteries. Increased capacity in relation to weight and size has become possible with the development of new types. The temperature range through which they can operate has been extended in an effort to meet atmospheric conditions of the tropics and the artic.

A main value of the text is in the description of new and unfamiliar types of primary batteries, and in modern explanation of the actions of older types made possible by the availability of the electron microscope, X-ray spectrograph, and the mass spectrograph for the purposes of research.

A battery is described for radio sonde uses which has two sections for A and B circuits of a small radio transmitter which is elevated into the upper atmosphere to report meteorological conditions, the A section of two cells having a voltage of 3.6, the B section of forty-nine cylindrical cells in honeycomb formation having a voltage of ninety. Recent primary battery developments include the powerful silver oxide and chloride cells capable of discharge at high rates and having a flat voltage characteristic.

There is a nostalgic note in the reference to copper sulphate, or bluestone batteries. It appears they began to disappear from telegraph and telephone offices and railroad signal service about thirty years ago when the cost of copper sulphate sky-rocketed. There are graying telegraph and telephone engineers who in pensive moments live over again the over-time (gratis) night hours they put in scraping crow-foot zinc electrodes and punching encumbrances away from overburdened copper elements.

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The Principles of Television Reception by A. W. Keen

Published (1949) by Sir Isaac Pitman and Sons, Ltd., London. 304 pages+5-page index+10-page appendix+xv pages. 235 figures. 5¾×9. 30/-.

This book was originally written for the engineers of a receiver manufacturer's servicing organization. It was designed to teach them the basic principles of television reception, including developments in color television, in a qualitative and theoretical fashion, i.e., without becoming involved in numerical and design details. It can also be recommended as a text for the general technical reader. Particular care has been taken to avoid mathematical complication, and the fundamental derivations have been placed in the appendix.

The electrical circuit material is well presented, and a background chapter on basic signal and circuit theory prepares one for the later discussions. There is also a background chapter on receiver testing, which is hardly enough instruction for a service man, but gives a good outline of the general principles in this aspect of the art. Another background chapter outlines the complete television process from the original scene on, and presents major British and American broadcast standards. The treatment becomes more sketchy when it comes to discussion of the visual performance of the receiver.

The book covers much of American as well as British practice in receiver design. The major difference between the two problems, namely, the number of simultaneous channels in use, and the consequent importance of image frequency response and local oscillator radiation in the American receiver, are covered rather briefly for the American reader.

In contrast with the general trend of the book to start from basic principles, the chapter on antenna theory and the discussion of colorimetry assume a higher degree of sophistication on the part of the reader. It is of course a severe task to compress a basic treatment of colorimetry into five pages, but the naïve reader, if he also sees other material on this subject, will be puzzled by the scaling of the three chromaticity diagram coordinates into equal units of brightness.

It is indicative of the rapid recent development in color television (characterized with apparent British understatement as "on a limited scale") that though the book was concluded in 1947, the descriptions of the color systems are now fairly well out-of-date.

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Patent Practice and Management for Inventors and Executives by Robert Calvert

Published (1950) by Scarsdale Press, Box 536, Scarsdale, N. Y. 331 pages+15-page index+xi pages +14-page appendix. 6×9¼. $5.00.

Written by Robert Calvert, Ph.D., variously chemist, college professor, industrial research director, and patent attorney, the book has been prepared for inventors and executives, as its title implies. It is useful also for engineers engaged in industry. It includes information on applications, patents, their processing, and their handling to a degree desirable for executives, supervising engineers, and independent inventors, and to a lesser degree to others employed in industry. The various subjects are covered in as great detail as the intended readers are likely to be able to absorb, but not in the full and thorough fashion of books written for a patent attorney.

For the executive, there are chapters on license of patents, misuse of patents, utilization of patents without license, sale, or suit, measure of liability for infringement, tax law involved in patents, and foreign patents, their advantages and disadvantages.

For the engineering supervisor there are chapters covering the phases of patent procurement necessary to understand how engineers can best co-operate in the patent aspects of their work to secure protection of their technical advances.

For the average engineer, besides the patent information, items of special interest occur in chapters on who is the inventor, special incentives for inventors and executives, and patent rights of employers and employees.

For the independent inventor, who is his own business executive as well as design and research engineer, most of the book is pertinent to his interests.

The book will not suffice to dispense with a patent attorney. It will, however, answer many questions that come to mind when the patent attorney is not available, and supply valuable information that a patent attorney will not think of imparting unless asked.

The book is well written and easily readable. It contains a glossary of patent terms, an appendix of license and other forms, as well as an index of cases and authorities including authors, and a subject index that appears ample.

R. A. Heising
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Murray Hill, N. J.

The Radio Manual by George E. Sterling and Robert B. Monroe

Published (1950) by D. Van Nostrand Co., Inc., 250 Fourth Ave., New York 3, N. Y. 879 pages+v pages+11-page index. 821 figures. 8×10. $12.00.

This revised edition although still primarily an operating manual has a wealth of background theory and fundamental data. The book is specifically directed at the commercial radio operator. It contains complete and specific operating and maintenance instructions on present day Marine, Emergency, AM & FM Broadcast and Television transmitters. Marine receivers and Lifeboat Equipment are thoroughly covered. The new chapter on Emergency Service Radio Equipment (Police, Fire, etc.) covers the complete systems including antennaes and operating procedures. The chapter on Marine Navigational Aids has been revised to include Radar and Loran, as well as ordinary direction find equipment. Chapters are also provided on Radio Frequency Measurements and Broadcast Studio and Control Room Equipment. Backing up the foregoing chapters on actual equipment are well written chapters on elementary electrical and radio theory. These cover electricity and magnetism, motors and generators, batteries, electron tubes, amplifiers and oscillators, amplitude and frequency modulation, radio wave propagation and antennas. The three final chapters cover the state, federal and international conventions and laws of radio. Particular attention is merited by the excellent chapter on television prepared by Dr. T. T. Goldsmith. In 72 pages he covers the general theory and complete details of the overall system including test equipment and operating procedure. The arrangement of the chapters in conjunction with a complete index facilitates the location of material. The book is clearly printed and the illustrations are excellent. It forms a valuable reference volume for any engineering library and is particularly recommended for students and commercial operators.

John D. Reid
American Radio and Television Inc.
North Little Rock, Ark.

High Speed Computing Devices by Staff of Engineering Research Associates, Inc.

Published (1950) by McGraw Hill Book Co., 330 W. 42 St., New York 18, N. Y. 440 pages+11-page index+xiii pages+60 figures. 9¼×6¼. $6.50.

This volume, which represents the combined efforts of a number of members of the staff of Engineering Research Associates, Inc., is a very welcome one, for it is the most up-to-date book on the subject of machine computation and contains a wealth of information not readily available elsewhere. According to the foreword, the book is based on a report submitted to the Office of Naval Research in fulfillment of a contract which called for "an investigation and report on the status of development of computing machine components." Reflecting this fact, the book presents essentially the results of a broad survey of the field of machine computation, with emphasis on high-speed computing devices.

The book is divided into three parts of about equal length. Part 1 begins with a general discussion of various types of computing machines. Following this are given descriptions of some of the basic computing elements such as flip-flop counters, switching and gating circuits, converters, buffers, and adders. The material covered in the next three chapters is of an altogether different nature. Chapter 5 is given over to a discussion of programming of computational processes and the organization of standards commands for the general-purpose machine. Chapter 6 presents a discussion of several counting systems: binary, decimal, biquinary, etc., and outlines the basic arithmetic operations in these systems. Chapter 7 is concerned with the basic techniques of numerical analysis. One finds here a very good treatment of various interpolation formulas, methods of numerical integration and the principal methods of solution of ordinary differential equations.

Part 2 is devoted to a discussion of various types of computing systems. Included here are descriptions of desk calculators, punched-card computers, and large-scale digital computing systems. In particular, the ENIC and the UNIVAC, Mark I and II Calculators, the IBM Selective Sequence Calculator, Bell Telephone Laboratories' Relay Computers, and ERA Computer are described in some detail. Analog computers are treated briefly in Chapter 11, and only a few pages are devoted to electronic differential analyzers.

The last part of the book contains much useful information about the basic arithmetic components: adders, subtractors, accumulators, and multipliers. The usual storage devices- delay lines, magnetic tape, punched tape, and cathode-ray storage tubes are treated in varying degrees of detail. The last chapters of the book are devoted in the main to a description of data conversion devices, from digital to analog, and vice versa, and to discussion of other auxiliary techniques and equipment.

The book has many valuable features, as well as some weaknesses. A particularly noteworthy feature is the unusually complete and up-to-date bibliography which is appended at the end of each chapter. Perhaps the most noticeable weakness is the lack of continuity in the treatment of various topics and unevenness in emphasis.

On the whole, the book constitutes a valuable addition to the literature of machine computation and is a "must" for all those who are concerned directly or indirectly with the theory and practice of computing devices.

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Electromagnetic Theory by Oliver Heaviside

Published (1950) by Dover Publications, Inc., 1780 Broadway, New York 19, N. Y. 386 pages+xxx pages. 9×12. $7.50.

This work constitutes one of the most readable classics of modern applied science, in one volume, unabridged. It was published originally in three volumes between 1891 and 1912. Heaviside intended to write a fourth volume, but circumstances intervened, and in publishing volume 3, in 1912, he incorporated material intended for volume 4.

This work incorporates treatment of more than 500 topics, including Maxwell's theory, eolotropic relations, electric stress in air, depth of the electrified layer on conductors, waves from moving sources, waves in the ether, sound waves, Lagrange's equations, etc. Heaviside was the first to investigate mathematically the problem of the coaxial cable. The consolidated work may be regarded as a summary of Heaviside's matured views on these subjects, concluded by challenging paragraphs on "Limitations on Scientific Prediction." The extended Introduction by Professor Ernst Weber is a critical and historical review of Heaviside's life and works.

In his published Notes of 1885–1886, Heaviside discussed the use of the terms resistivity, permeability, capacity, etc., and he expressed alarm as to "the frightful names that might have been given the electrical units by the Germans." The salty and incisive language of Heaviside's writings is refreshing and inspirational. He enjoyed tilting with the Cambridge mathematicians because of their "distressing and soul-destroying style in doing their work." Actually, Heaviside's unorthodox methods were so sketchily explained as to shock the conservative rigorists of the time. Heaviside's writings disclose that he had unbounded admiration for Maxwell's Theory unifying the known facts of electrostatics, electrokinetics, and electromagnetics—at the time of Maxwell's death in 1879, still speculative because no experimental evidence of wave propagation had been given. Thenceforth Heaviside asserted himself as a vigorous disciple of Maxwell.

Heaviside, like Edison and a host of other men who achieved renown, in his youth became a telegraph operator and took advantage of opportunities incidental to such employment to study and experiment.

The publication of this work places Heaviside's writings within reach of all colleges and technical schools, as well as of earnest students who realize the direct value of personal libraries.

Donald McNicol
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Wave Filters by L. C. Jackson

Published (1950) by John Wiley and Sons, Inc., 440 Fourth Ave., New York 16, N. Y. 103 pages+2-page index+vii pages. 64 figures. 4¼×6¾. $1.25.

This book is a third edition of one of the handy pocket sized Methuen's monographs on physical subjects and was first published in 1944.

The author's intention is to strike a happy medium between standard treatises on wave filters, and the brief treatments given in texts on general communication engineering. Unfortunately, the result is a rather uninspired collection of formulas for conventional filter types, with slightly more explanation than is found in the usual handbook treatment. No mention is made, either in the text or bibliography, of the modern filter design methods of Guillemin, Bode, Ralington, and others.

Other filter types are discussed briefly, including coupled circuits, quartz crystals, coaxial lines, and mechanical and acoustic applications.

C. W. Carnahan
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Albuquerque, N. M.

Circuits in Electrical Engineering by Charles R. Vail

Published (1950) by Prentice-Hall, Inc., 70 Fifth Avenue, N. Y. 497 pages+12-page index+xv pages. 206 figures. 6×8½. $7.65.

This book was written to cover the "demands . . . made of electric circuits courses by the typical modern electrical engineering curriculum." "An introductory course in electrical engineering is not absolutely essential to successful use of the book, A knowledge of mathematics through basic calculus is assumed." Whether the book is intended for the circuits courses of the whole curriculum or for only the first introductory course is not stated. This is important, since repetitive networks such as filters and transmission lines are not mentioned, although an introduction to transient theory is included.

The book evokes a curious combination of reactions from this reviewer. From many angles it is just another elementary textbook. The tedious detail of many of the analyses (such as reactive power) would seem unnecessary for students of average ability. In fact, the student might well profit by doing the detailed development of such relationships for himself. The problems are humdrum and routine, so that no play of imagination is invited.

Yet there are certain excellent features about the book. The drill is thorough, so that the student should certainly grasp the mechanics of the techniques discussed. The concept of the principle of duality in circuit theory is well discussed. And the balanced discussion of complicated networks from the loop and node points of view should prove extremely useful to the student in his later work. All of the treatment is given for the general case of any frequency including direct current.

In short, the point of view is excellent, the treatment pedestrian.

Knox McIlwain
Hazeltine Electronics Corp.
Little Neck, L. I., N. Y.

Abstracts and References

Prepared by the National Physical Laboratory, Teddington, England, Published by Arrangement with the Department of Scientific and Industrial Research, England, and *Wireless Engineer*, London, England

NOTE: The Institute of Radio Engineers does not have available copies of the publications mentioned in these pages, nor does it have reprints of the articles abstracted. Correspondence regarding these articles and requests for their procurement should be addressed to the individual publications, and not to the IRE.

The number in heavy type at the upper left of each Abstract is its Universal Decimal Classification number and is not to be confused with the Decimal Classification used by the United States National Bureau of Standards The number in heavy type at the top right is the serial number of the Abstract. DC numbers marked with a dagger (†) must be regarded as provisional.

The Annual Index to these Abstracts and References, covering those published in the PROC. I.R.E. from February, 1949, through January, 1950, may be obtained for 2s. 8d. postage included from the *Wireless Engineer*, Dorset House, Stamford St., London S. E., England. This index includes a list of the journals abstracted together with the addresses of their publishers.

ACOUSTICS AND AUDIO FREQUENCIES

016:534 2682

References to Contemporary Papers on Acoustics—A. Taber Jones. (*Jour. Acous. Soc. Amer.*, vol. 22, pp. 522–528; July, 1950.) Continuation of 2395.

534.231 2683

The Propagation of a Sound Pulse in the Presence of a Semi-Infinite Open-Ended Channel: Part 1—W. Chester. (*Phil. Trans. A*, vol. 242, pp. 527–556; September 5, 1950.) Two problems are discussed. In the first, a sound pulse originates inside a duct between two semi-infinite parallel planes and travels to and beyond the open end, where it undergoes partial reflection. In the second case, the pulse originates outside the duct and approaches the open end from an arbitrary direction. A succession of diffracted waves is created at the end of the duct, for which in the first case a general formula is derived by operational methods. A simple reciprocity relation is applied to deduce the form of the wave in the duct in the second case. Ultimately the returning wave becomes sensibly plane and splits up into regions of length equal to the distance between the boundary planes, the form of the potential depending on the number of diffracted waves which contribute to each particular region. Explicit expressions are obtained for the potential in the first two regions at the head of the returning wave and for the third region when the pulse originates within the duct. The case of an initial velocity distribution given by the Heaviside unit pulse is treated in detail.

534.232:534.321.9 2684

The Relative Output from Magnetostriction Ultrasonic Generators—F. M. Leslie. (*Jour. Acous. Soc. Amer.*, vol. 22, pp. 418–421; July, 1950.) Equivalent transmission-line circuits are used to develop formulas for the resonance frequency and output of the simple bar oscillator and the dumbbell type. Approximations in the latter case do not introduce any great discrepancy between calculated and measured values of resonance frequency. The formulas, though applicable directly to the symmetrical dumbbell oscillator, may be easily applied to the asymmetrical oscillator and to those in which the face area is less than the cross-section of the neck.

534.232:534.321.9:621.3.087.6 2685

Application of Supersonic Energy to High Speed Electronic Recording—H. J. Dana and J. L. Van Meter. (*Proc. NEC* (Chicago), vol. 5, pp. 473–476; 1949.) See 1561 of August.

534.24:532.582.3 2686

Sound Scattering from a Fluid Sphere—V. C. Anderson. (*Jour. Acous. Soc. Amer.*, vol. 22, pp. 426–431; July, 1950.) A mathematical solution is obtained for scattering from a sphere of size comparable with the wavelength, with acoustic properties near to those of the surrounding medium. The reflectivity for direct backward scattering is presented as a function of relative density and relative sound velocity. Comparison is made with the Rayleigh limiting case and with the case of a fixed rigid sphere. For diameters comparable with the wavelength, scattering may show pronounced maxima and minima.

534.373:534.213.4 2687

Classical Viscosity in Tubes and Cavities of Large Dimensions—B. P. Bogert. (*Jour. Acous. Soc. Amer.*, vol. 22, pp. 432–437; July, 1950.) "A method for the calculation of viscous losses in acoustic wave guides and cavities is described, similar to that used by Carson, Mead, and Schelkunoff for electromagnetic waves. The loss in a plane wave in a round tube is discussed and the results agree with those previously obtained by others. The attenuation for two higher modes in hard-wall guides is computed, as well as the decay constants for a cylindrical cavity for longitudinal and pure radial modes."

534.414 2688

Acoustic Resonators of Circular Cross-Section and with Axial Symmetry—A. K. Nielsen. (*Trans. Dan. Acad. Tech. Sci.*, no. 10, 70 pp; 1949. In English.) The literature on this subject is critically reviewed. The usual approach to resonator theory is inadequate for two reasons. Firstly, the velocity distribution in the coupling aperture is usually assumed constant in order to satisfy boundary conditions. This assumption actually violates the boundary condition at the sharp edges of the coupling aperture, where the velocity becomes infinite (neglecting losses). Secondly, the interaction between the wave emitted from the coupling aperture and that reflected from the cylindrical walls of the resonator has been neglected. An expression for the velocity distribution is derived which satisfies the rise-to-infinity condition at the edge of the aperture and a formal solution of the wave equation is obtained, assuming the velocity distribution in the aperture to be known. The results are used to calculate the resonance frequency of a symmetrical resonator by the energy method. Formulas are also given for asymmetrical resonators. The end correction for a flanged organ pipe is found to be $0.8220r$, a slightly better approximation than Rayleigh's value of $0.8242r$. The effects of viscosity and heat conduction are also considered. Experimental results for various resonators and flanged organ pipes agreed with the theoretical values to within 1 per cent.

534.417:621.395.614† 2689

Crystal Microphone for Underwater Sounds—W. Guttner. (*Z. Angew. Phys.*, vol. 2, pp. 206–210; May, 1950.) The microphone consists of 10 Rochelle-salt plates with 45° X-cut mounted between elastic supports so that the sound pressure acts only on the front membrane. Its response characteristic is shown; this is largely independent of temperature change. The method of calibration is described The measured response of the receiver agrees well with values calculated from crystal data.

534.442 2690

Methods and Instruments for the Visual Analysis of Complex Audio Waveforms—H. R. Foster and E. E. Crump. (*Proc. NEC* (Chicago), vol. 5, pp. 564–572; 1949.)

534.442.2:621.392.52 2691

A Continuously Variable Filter—C. G. M. Fant. (*Jour. Acous. Soc. Amer.*, vol. 22, pp. 449–453; July, 1950.) A heterodyne filter for the speech frequency range is described. Band-pass filtering with continuously variable low- and high-frequency cutoffs or band-elimination filtering with variable mid-frequency and fixed bandwidth are possible. Variable filtering is performed by ssb transmission with successive filtering and demodulation. The filter was designed for speech investigations and wave analysis in the range 40–2,000 cps.

534.75:534.792 2692

The Frequency Selectivity of the Ear as Determined by Masking Experiments—T. H. Schafer, R. S. Gales, C. A. Shewmaker, and P. O. Thompson. (*Jour. Acous. Soc. Amer.*, vol. 22, pp. 490–496; July, 1950.)

534.78:621.314.26 2693

Devices for Speech Analysis and Compression—F. Vilbig. (*Proc. NEC* (Chicago), vol. 5, pp. 573–581; 1949.)

534.833.4 2694
Acoustic Materials—(*Tech. Bull. Nat. Bur. Stand.*, vol. 34, pp. 96–102; July, 1950.) A review of the essential theory of sound absorption, the principles governing the use of absorptive materials, the various types of such materials, their physical properties and methods of measurement.

534.846.6 2695
The Use of Three-Dimensional Models in Room Acoustics—R. W. Muncey. (*Jour. Acous. Soc. Amer.*, vol. 22, pp. 510–511; July, 1950.) The chief difficulty in the construction and use of models for investigation of room acoustics is the provision of bounding surfaces to simulate the properties of those of the full-size hall. Investigations of the use of small-scale models has been commenced in the Building Research Laboratory, Victoria, Australia.

621.3.018.78:621.317.79† 2696
An Intermodulation Analyzer for Audio Systems—Fine. (*See* 2840.)

621.395.612.45 2697
New "Unobtrusive" Ribbon Pressure Microphone—H. F. Olson and J. Preston. (*Broadcast News*, pp. 24–28; May and June, 1950. *Audio Eng.*, vol. 34, pp. 18–20; July, 1950.) Theory and description of a microphone with uniform response from 50 cps to 15 kc. A small pickup horn applies sound pressure to the ribbon through a cylindrical tube and tapered connector, the back of the ribbon being coupled to the damping labyrinth by a similar connector.

621.395.623.7 2698
Electroacoustic Phase Shift in Loudspeakers—C. A. Ewaskio and O. K. Mawardi. (*Jour. Acous. Soc. Amer.*, vol. 22, pp. 444–448; July, 1950.) The modulation phase-shift method of Nyquist and Brand was adapted for direct indication of envelope delay (the slope of the phase-shift curve) by using an electronic phase-meter. A continuous record was obtained of the delay for various loudspeakers by means of an automatic level recorder suitably connected to the phase-meter. The results, together with pressure-amplitude response curves, may serve as a basis for assessing the quality of a loudspeaker.

621.395.625.3:681.6 2699
Duplication of Magnetic Tape Recordings by Contact Printing—Herr. (*See* 2804.)

621.395.625.3:681.6 2700
A New Magnetic Record Duplicating Process—Camras. (*See* 2803.)

681.85 2701
A Variable Speed Turntable and its Use in the Calibration of Disk Reproducing Pickups—H. E. Haynes and H. E. Roys. (*Proc. NEC* (Chicago), vol. 5, pp. 556–563; 1949.) See 1578 of August.

681.85:534.862.4 2702
The Diamond as a Phonograph Stylus Material—E. J. Marcus and M. V. Marcus. (*Audio Eng.*, vol. 34, pp. 25–27, 41; July, 1950.) The properties of natural diamonds, which make them pre-eminent for use as stylus points, are described, and a photographic comparison is made of the normal wear of commonly used stylus materials, showing the very great superiority of the diamond. Natural small stones, owing to their greater structural strength, are better than chips cut from larger gem stones. A short account is given of the occurrence of the stones and of the methods of preparing them for use.

534.321.9:[5+6 2703
Der Ultraschall und seine Anwendung in Wissenschaft und Technik (Ultrasonics and its Application in Science and Technology) [Book Review]—L. Bergmann. Publishers: S. Hirzel Verlag, Zürich, 5th edn 1949, 748 pp., 50 Swiss fr. (*Jour. Acous. Soc. Amer.*, vol. 22, p. 517; July, 1950.) "The author has rendered a genuine service to all workers in ultrasonics and allied fields by bringing together so much valuable material in one place and organizing it so systematically and efficiently. No worker in the field can really afford to have this book very far away from his desk." Over 2,300 references are included. The 3rd edition was noted in 280 of 1946.

534.833.4 2704
Sound-Absorbing Materials [Book Review]—C. Zwikker and C. W. Kosten. Publishers: Elsevier Publishing Co., 1949, Amsterdam, Brussels, and New York; Cleaver-Hume Press, London, 1949, 174 pp., $3.00 (*Research* (London), vol. 3, pp. 281–282; June, 1950.) "A highly scientific study of the physical behavior of sound waves impinging on and penetrating into absorbent constructions of any type."

534.84 2705
Acoustical Designing in Architecture [Book Review]—V. O. Knudsen and C. M. Harris. Publishers: J. Wiley and Sons, New York, 1950, 404 pp., $7.50. (Proc. I. R. E., vol. 38, p. 832; July, 1950.) A nonmathematical presentation. A little space is devoted to discussion of sound-amplification systems and studio design. Tables of sound-absorption coefficients and sound-insulation data are brought together in the appendices.

ANTENNAS AND TRANSMISSION LINES

621.392.26† 2706
Some Properties of Waveguides with Periodic Structure—A. W. Lines, G. R. Nicoll, and A. M. Woodward. (*Proc. IEE* (London), Part III, vol. 97, pp. 263–276; July, 1950.) A general description of the frequency characteristics of waveguides with periodic structure is derived from a discussion of loaded transmission lines. Analysis of an equivalent circuit is used to give a detailed confirmation of these characteristics. The periodic guide with systematically detuned resonators is then examined by these methods, all the general features being obtained by elementary reasoning. A more detailed treatment, based on Maxwell's equations, is required for specific design problems and this is employed in the design of a periodic waveguide with every third resonator detuned, for which a space harmonic exists with constant phase velocity over a wide frequency band. Possible experimental techniques for checking the theoretical frequency characteristics are discussed and the results obtained by one technique for the constant-phase-velocity guide are given.

621.392.26†:621.3.09 2707
Electromagnetic Waves in Circular Wave Guides Containing Two Coaxial Media—R. D. Teasdale and H. J. Higgins. (*Proc. NEC* (Chicago), vol. 5, pp. 427–441; 1949.) The general problem is treated in detail. A conditional equation governing propagation in such waveguides is derived. The two conditions for which simple E or H waves can be propagated are determined and discussed. Curves relating phase velocity to design parameters are plotted for the E_0 wave and examples are discussed for which the general solution reduces to particular solutions given by other authors.

621.392.26†:621.3.09 2708
On the Theory of Electromagnetic Radiation in Metal Tubes—R. Honerjager. (*Zeit. für Phys.*, vol. 128, pp. 72–78; June 20, 1950.) The radiation field of an electric and magnetic dipole of given moment in an infinitely long straight metal tube of arbitrary cross-section is calculated for E and H waves, and also the total em power flux through the tube.

621.396.67+621.396.611.1 2709
A Combination Slot Antenna and Resonant Tank Circuit—N. L. Harvey. (*Proc. NEC* (Chicago), vol. 5, pp. 183–189; 1949.) An impedance transforming and coupling network is usually required between the transmitter unit and the antenna. The coupling network can be eliminated by using the edges of the antenna slot as the resonant circuit of the transmitter unit. Such an arrangement is especially suitable for wide-band applications.

621.396.67 2710
Impedance and Radiation Characteristics of Slotted-Cylinder Antennas—R. E. Beam and H. D. Ross, Jr. (*Proc. NEC* (Chicago), vol. 5, pp. 172–182; 1949.) Approximate theoretical expressions are developed for the input impedance and radiation patterns of a slotted-cylinder antenna with a narrow slot of length equal to or greater than the free-space half wavelength, and fed at the midpoint of the slot. The antenna is considered as a slot-loaded cylindrical waveguide in calculating the cut-off frequency and phase constant along the slot. Babinet's principle is applied to the determination of the radiation resistance. Experimental results are in good agreement with theory.

621.396.67 2711
Slot Radiators—N. A. Begovich. (Proc. I.R.E., vol. 38, pp. 803–806; July, 1950.) By an extension of Babinet's principle Booker has shown (1335 of 1947) that the field pattern of a slot antenna is identical with that of the corresponding wire antenna, but with the electric and magnetic fields interchanged. A rigorous proof of this is now given, using the double-current-sheet diffraction formula. Integration of Poynting's vector over both surfaces of the slot gives a driving impedance of $362.5+j210.5$. The real part of this is in excellent agreement with experimental measurements. The mutual impedance between slots, necessary for array calculations, is also determined.

621.396 2712
The Slot Radiator, a Magnetic Dipole for Centimetre Waves—H. Severin. (*Zeit. für Phys.*, vol. 128, pp. 108–119; June 20, 1950.) The slot radiator is represented as a magnetic dipole and its mode of operation by the theory of diffraction of em waves at a small aperture in a perfectly conducting screen. Measured values of the radiation from and magnetic moment of small elliptical-slot radiators disposed respectively parallel and perpendicular to the magnetic field of the incident wave are in good agreement with calculations, provided the linear dimensions of the apertures are $<\lambda/3$.

621.396.67 2713
Correction of Spherical Aberration by a Phased Line Source—R. C. Spencer, C. J. Sletten, and J. E. Walsh. (*Proc. NEC* (Chicago), vol. 5, pp. 320–333; 1949.) Theory of the spherical reflector with corrected line source is developed. Tests using feeds such as open waveguides, horns, polyrod, slotted and dipole line sources show that if the phasing is suitably adjusted, aberrationless scanning of a pencil beam over at least $\pm 30°$ in any direction can be achieved.

621.396.67 2714
The Electromagnetic Field in the Vicinity of a Linear Conductor—P. H. Nelson. (*Proc. NEC* (Chicago), vol. 5, pp. 315–319; 1949.) A study is made of the interference pattern in

the vicinity of a linear conductor, of infinite length and zero resistance, subjected to the action of a plane em wave with electric-field vector parallel to the conductor. The reradiated field is independent of the incident field except at the surface of the conductor, so that superposition of the incident and radiated fields gives the interference pattern required. Experiments at a frequency of 3,000 Mc with some simple types of conductor gave results in close agreement with theoretical calculations.

621.396.67 2715
End-Loaded and Expanding Helices as Broad-Band Circularly Polarized Radiators—P. W. Springer. (*Proc. NEC* (Chicago), vol. 5, pp. 161–171; 1949.) The simplicity of the axial-mode helix makes it particularly suitable for the radiation of circularly polarized waves, but for applications requiring either modified radiation patterns or broad transmission bands it is often necessary to modify the simple helix. Two types, the short end-loaded helix and the expanding helix, are of particular value where extreme bandwidths are required. The theory of operation, impedance curves, polar diagrams, current and phase distribution are discussed and arrays are described providing (*a*) broad azimuth coverage, (*b*) sharp radiation patterns.

621.396.67 2716
Antifading Broadcast Antenna—H. Brueckmann. (*Electronics*, vol. 23, p. 228; August, 1950.) Correction to article abstract in 1863 of September.

621.396.67:621.317.79 2717
The Electronically Driven Ripple-Tank as an Aid to Phase-Front Visualization—Schooley. (*See* 2841.)

621.396.67:621.392.26† 2718
The Channel-Guide Antenna—W. Rotman. (*Proc. NEC* (Chicago), vol. 5, pp. 190–202; 1949.) The general condition for radiation from the slot of a channel-guide antenna is derived in terms of the near-field distribution of em energy, which may be described as a form of single-mode transmission in the supporting waveguide, characterized by a complex propagation constant. A method of computing the propagation constant gives results for different channel geometries which are in agreement with experiment. Practical methods of coupling channel-guide antennas to microwave sources are considered.

621.396.67:621.397.62 2719
An Automatic Built-In Antenna for Television Receivers—K. Schlesinger. (*Proc. NEC* (Chicago), vol. 5, pp. 292–302; 1949.) See 819 of May.

621.396.67.012 2720
A Graphical Analysis of the Interference Patterns of an Elevated Ultra-High-Frequency Antenna under Conditions of Atmospheric Stratification—F. R. Abbot and C. J. Fisher. (*Jour. Appl. Phys.*, vol. 21, pp. 636–641; July, 1950.)

621.396.67.029.64:535.42 2721
Small-Surface Microwave Diffraction—A. Applebaum and P. C. Fritsch. (*Proc. NEC* (Chicago), vol. 5, pp. 442–449; 1949.) The diffraction of plane-polarized em waves by reflection from small perfectly conducting surfaces (diameter of the order of λ) is calculated for any angle of incidence by Schelkunoff's "current-sheet" method. A correction for boundary effects is determined. Experimental results obtained with an unmodulated reflex klystron, Type 2K39, as the power source, are in good agreement with theory.

621.396.673:621.397.61 2722
1057-Foot FM-TV Antenna—(*Broadcast News*, no. 59, pp. 8–15; May and June, 1950.) Situated at Atlanta, Ga., a 1,000-ft tower supports an RCA Supergain television antenna (1865 of September). Above this is a FM antenna, a 4-section pylon, RCA Type BF-14D. The television antenna has a gain of 11.5, which, with a 5-kw transmitter, gives an effective radiated power of 52 kw. The FM antenna has a power gain of 6; provision is made for an additional four sections to double this gain. The earthing system consists of radial copper straps 50 ft. long spaced every five degrees, buried 6 in. deep and terminating in copper earthing rods.

621.396.677 2723
A Wide-Angle Microwave Radiator—S. S. D. Jones. (*Proc. IEE* (London), Part III, vol. 97, pp. 255–258; July, 1950.) If a glass sphere of unit radius could be produced with a refractive index $\mu=\sqrt{(2-r^2)}$ where r is the radial distance from the centre, the sphere would act as a lens with a focus on the surface of the sphere. A microwave analogue has been constructed using spaced conducting sheets. The lens is free from aberrations as the feed is moved around the circumference and is therefore suitable for wide-angle scanning. The measured performance agrees well with theory.

621.396.677:538.31:538.214 2724
The Effective Permeability of an Array of Thin Conducting Disks—Estrin. (*See* 2765.)

621.396.677.2 2725
Theoretical Investigations on the Radiation Impedance of Transmitting Aerials—J. Patry. (*Schweiz. Arch. Angew. Wiss. Tech.*, vol. 16, pp. 138–147; May, 1950.) The theory of Hallen is extended to antenna arrays, in particular to symmetrical dipole arrays for metre waves. The two special problems considered are the interaction of parallel dipoles with parallel feed and the effect of the spacing between the two elements of a dipole. The complex general formula is simplified for the resonance case treated here. The values of expressions from which the radiation resistance can be found are given in a table referring to 12 different arrays of similar dipoles.

CIRCUITS AND CIRCUIT ELEMENTS

621.314.2.018.424.029.3 2726
Audio-Frequency Transformer with Range Extended Below One Cycle Per Second—D. W. Kuester. (*Proc. NEC* (Chicago), vol. 5, pp. 255–257; 1949.) Discussion of design problems and description of a transformer for connection between a 72-Ω line and a 10-kΩ grid circuit, with a flat response curve from 0.2 cps to 20 kc.

621.314.263 2727
The Magnetic-Cross Valve and its Application to Subfrequency Power Generation—H. J. McCreary. (*Proc. NEC* (Chicago), vol. 5, pp. 450–466; 1949.) Basic theory and characteristics are discussed, showing how subharmonics may be obtained by a process of magnetic energy transference without moving parts or mutual inductance. Results of experimental analysis are used to show how a single flux vector may vary cyclically, but with different periods along two axes, resulting in the production of sub-harmonics. Details are given of the performance of a "Power Ringer" employing the device; this converts 60 cps power to 20 cps and has been in use in a telephone exchange for 4 years without attention.

621.314.3† 2728
The Magnetic Amplifier—J. S. W. Graham. (*Strowger Jour.*, vol. 7, pp. 104–119; July, 1950.) Fundamental principles are outlined and power control, amplification ratio, continuously variable control, feedback, time lag core materials, and general design features are considered in detail. Application to rhythmic ("rhythmatic") ripple control is described, with test results.

621.314.3† 2729
The Problem of the Magnetic Amplifier and Some Approaches to Its Solution—M. Liwschitz-Garik, E. J. Smith, and E. Weber. (*Proc. NEC* (Chicago), vol. 5, pp. 235–254; 1949.) Various possible methods of steady-state analysis are considered and the question of the best representation of the magnetization characteristic of a core under conditions of asymmetrical magnetization is discussed. Experimental results are given illustrating the effect of dc bias on the ac magnetization curve. Results for half-wave and full-wave magnetic amplifiers are computed by a point-by-point procedure and by a method based on the representation of the magnetization curve by three linear elements. The latter method yields satisfactory results in much the shorter time.

621.314.3† 2730
An Extension of a Theory of Magnetic Amplifiers—R. T. Beyer and Ming-Yi Wei. (*Jour. Frank. Inst.*, vol. 250, pp. 25–37; July, 1950.) The theory previously given (2730 of 1949) is extended to the case of large dc inputs and the presence of harmonics in the primary current, the ac impedance of the secondary being assumed infinite. Experimental evidence supports the calculations, which show a nonlinear relation between dc input and second-harmonic output, the latter passing through a maximum as the ac is increased. The influence of a third-harmonic component in the primary current is also investigated; for small input currents it may be neglected without serious error.

621.314.3†:681.142 2731
Magnetic Amplifier Studies on the Analog Computer—E. L. Harder, W. H. Hamilton, D. F. Aldrich, J. T. Carleton, and F. N. McClure. (*Proc. NEC* (Chicago), vol. 5, pp. 222–234; 1949.) A description is given of an electrical analogue to magnetic circuits and its application to the study of such circuits. Methods of applying the analogue to specific design problems are discussed. The nonlinear characteristics of iron are reproduced by using a multiple-diode nonlinear-resistance circuit, whose characteristic simulates the true B/H curve by means of 20 successive linear elements.

621.316.842+621.316.86 2732
Wideband Power Resistors—H. L. Krauss and P. F. Ordung. (*Electronics*, vol. 23, pp. 186–194; August, 1950.) A 30-w carbon-film resistor 10 in. long and $1\frac{1}{8}$ in. in diameter provided a satisfactory reactance-free 500-Ω termination up to 50 Mc when mounted in free space, but not when near an earthed plane, owing to stray capacitance. A terminated wire-wound resistor with 8 turns/in. on a former 1 in. in diameter, with carbon resistors connecting it to the earthed plane at suitable intervals so as to satisfy the distortionless transmission-line equation $R/G=L/C$, gave very satisfactory results up to 50 Mc.

621.318.572 2733
Electronic Decade Counter with Direct Indication by means of Neon Lamps—A. Peuteman. (*Compt. Rend. Acad. Sci.*, *Paris*, vol. 230, pp. 2160–2162; June 19, 1950.) See also 660 of 1949 (Naslin and Peuteman).

621.318.572:621.3.015.7 2734
A Pulse Length Sorter and Counter—R. J. Parent and R. W. Schumann. (*Proc. NEC* (Chicago), vol. 5, pp. 72–92; 1949.) Pulses of random length and spacing, which occur at a rate of up to 10^3 per minute, can be sorted according to duration into 15 ranges. Sorting

s achieved by biased circuits fed from a step-wave circuit driven by a multivibrator, which is gated by the random pulses to be measured. The number of pulses in each range is counted by binary scaling chains following each bias circuit. Circuits are described in detail, with the aid of diagrams and waveforms.

621.319.42 2735

The Influence of Operating Conditions on the Construction of Electrical Capacitors—A. E. Bennett and K. A. Gough. (*Proc. IEE* (London), Part III, vol. 97, pp. 231–241; July, 1950.)

621.392 2736

The Design of Wide-Band Phase-Splitting Networks—W. Saraga. (Proc. I.R.E., vol. 38, pp. 754–770; July, 1950.) A general investigation of phase-splitting networks, dealing with network analysis, network synthesis, and performance-curve approximation problems. Explicit formulas for any number of design parameters and for any required degree of approximation are stated for Taylor and Tchebycheff approximations. Clear design instructions for both simple and difficult network specifications are obtained. Novel methods are developed for obtaining dissipation compensation, for network synthesis, and for representing the approximating curves as iterated functions of two variables, with fractional index of iteration.

621.392.5 2737

Frequency Analysis of Variable Networks—L. A. Zadeh. (Proc. I.R.E., vol. 38, p. 725; July, 1950.) Corrections to paper abstracted in 1617 of August.

621.392.5:621.3.015.7† 2738

The Determination of the Impulsive Response of Variable Networks—L. A. Zadeh. (*Jour. Appl. Phys.*, vol. 21, pp. 642–645; July, 1950.) "Starting with the differential equation relating the output and the input of a linear varying-parameter network, it is shown that the impulsive response of the system is related to a Green's function associated with the system through a linear operator which is the adjoint of the right-hand operator in the given differential equation. A perturbation procedure [2835 of 1948 (Gray and Schelkunoff)] for the determination of the impulsive response of a slowly varying network is outlined. Use of the method is illustrated by a simple example involving a bandwidth-modulated RC half-section."

621.392.52 2739

Continuously Adjustable Electronic Filter Networks—G. E. Tisdale. (Proc. I.R.E., vol. 38, pp. 796–798; July, 1950.) The use of passive RC networks is discussed in terms of standard network theory. Frequency response is largely determined by these passive networks, while valves serve to isolate the various RC sections, to raise the output level, and to provide negative feedback. Design procedure is indicated and applied to adjustable low-pass and high-pass filters.

621.392.52 2740

A Crystal Filter of Variable Selectivity with Stable Resonance Frequency and Constant Gain—W. Kautter. (*Rev. Telegr.*, (Buenos Aires), vol. 37, pp. 137–142; March, 1949.) Basically, the filter consists of two intermediate-frequency amplifier units coupled by the crystal. The bandwidth is altered by detuning the two circuits in opposite directions: the resulting resonance shift is $<b_{max}/24$, where b_{max} is the maximum bandwidth, and thus falls within tolerable limits. The crystal dynamic resistance does not affect the operation of the filter, at least to a first approximation. The gain is constant and equal to that of a conventional intermediate-frequency stage over the whole band. Neutralization of the crystal dynamic capacitance, and the type of coupling required between crystal and circuits, are discussed. Crystals that are free from spurious responses near the working frequency are essential.

621.392.52:621.3.015.3 2741

Transient Response of Filters—M. S. Corrington. (*Proc. NEC* (Chicago), vol. 5, pp. 519–549; 1949.) Reprint. See 60 of February.

621.392.52:621.392.26† 2742

Low-Q Microwave Filters—J. Reed. (Proc. I.R.E., vol. 38, pp. 793–796; July, 1950.) An analysis of waveguide bandpass filters of the type previously investigated by Pritchard (1000 of 1948), Fano and Lawson (695 of 1948) and Mumford (1320 of 1949), in which each stage comprises two spaced inductive irises and successive stages are separated by $\lambda/4$ sections of optimum length $s+\lambda g/4$, where s is the iris spacing. Variation with frequency of the iris susceptance has a substantial effect on the loaded Q, especially for low values of Q. The theory was checked by experiments in which pairs of brass rods were substituted for irises

621.392.52:621.392.26† 2743

Design Relations for the Wide-Band Waveguide Filter—S. B. Cohn. (Proc. I.R.E., vol. 38, pp. 799–803; July, 1950.) Simplified formulas are derived and presented graphically for the design of nonuniform waveguide structures of the type previously considered (2469 of 1949). A numerical example is worked out. Measurements were made on specially constructed waveguide sections, and the calculated values of cut-off and infinite-attenuation frequency were found reliable to within 2 per cent.

621.392.52.029.4 2744

Continuously Adjustable Low- and High-Pass Filters for Audio Frequencies—A. Peterson. (*Proc. NEC* (Chicago), vol. 5, pp. 550–555; 1949.) Audio-frequency filter circuits are described in which the cut-off frequency is continuously variable over a 3:1 range with little change in the pass-band response. Each filter section uses two capacitors, a low-Q inductor, and a twin-triode reactance circuit with control by a single potentiometer. Beyond cut-off the attenuation is about 18 db per octave.

621.396.611.3 2745

An Analysis of Triple-Tuned Coupled Circuits—N. W. Mather. (Proc. I.R.E., vol. 38, pp. 813–822; July, 1950.) Circuits having high Q are considered, the couplings being loose and the response symmetrical about a reference frequency. Universal response curves are derived and contour plots for the product of gain and bandwidth are given. Compared with double-tuned circuits the triple-tuned circuit has the advantages of more uniform response inside the pass band, greater rejection outside it, and a larger value for the product of gain and bandwidth.

621.396.611.4 2746

Coupling between Two Degenerate Modes through Slots Cut in the Wall of a Cavity—Han C. Hu. (*Proc. NEC* (Chicago), vol. 5, pp. 467–472; 1949.) An analytical and graphical presentation of slot patterns is given. Experimental results obtained with a test cavity, and oscillograms showing transmission and absorption characteristics for TE_{112} and TE_{113} degeneracy, are used to indicate a way of achieving a precise degree of coupling.

621.396.615.14:621.385.029.63/.64 2747

The Helix as Resonator for Generating Ultra High Frequencies—van Iperen. (*See* 2944.)

621.396.645 2748

A 60-db Nonlinear Amplifier—J. A. Carruthers. *Canad. Jour. Res.*, vol. 28, pp. 287–292; May, 1950.) The amplifier described has been used to drive an Esterline Angus 0-1-mA recording galvanometer as part of the apparatus for automatically recording the radiation patterns of microwave antennas. By using automatic value control, the amplifier output is made approximately proportional to the logarithm of the input, thus enabling a 60-db variation of input signal to be plotted. The speed of response is limited by the galvanometer movement, but is adequate for obtaining a pattern through 100° of azimuth in about two minutes. Plotting is accurate to within 1 db if care is taken to check calibration frequently.

621.396.645 2749

Cathode-Follower Amplifiers—F. Navascues. (*Rev. Telecomun.* (Madrid), vol. 5, pp. 9–29; December, 1949.) Study of cathode-follower circuits for audio-frequency, low-frequency and high-frequency amplifiers, attenuators and impedance-matching units.

621.396.645 2750

Distributed Amplifiers: Practical Considerations and Experimental Results—W. H. Horton, J. H. Jasberg, and J. D. Noe. (Proc. I.R.E., vol. 38, pp. 748–753; July, 1950.) Experimental results are presented corroborating the predictions made in an earlier (3375 of 1948). The causes of deviation from the idealized case are (*a*) attenuation due to coil losses, (*b*) attenuation due to grid losses, (*c*) grid- and anode-lead inductance, (*d*) capacitance distributed throughout the transmission-line coil windings. These effects can be corrected by using paired-anode circuits, negative-mutual circuits, or bridged-T circuits. The pass bands dealt with are of the order of 200–300 Mc.

621.396.645:621.396.822 2751

Noise Suppression in Triode Amplifiers—A. van der Ziel. (*Canad. Jour. Res.*, vol. 28, pp. 189–198; June, 1950.) A survey is given of recent work on noise suppression in triode amplifier stages. A theory is developed, in which the noise factor is expressed in terms of four complex quantities g_0, g_1, i_0 and i_1, g_0 and g_1 are the complex transconductances in the cathode lead and in the anode lead, respectively; i_0 and i_1 are the Fourier components of the noise currents flowing in these leads, respectively. These quantities are complex owing to transit time effects. The theory is developed under the assumption that i_0 and i_1 are completely correlated. Experiments indicate that no complete noise suppression is possible if there is no feedback; according to the above theory this means that the real part of $g_0-g_1i_0/i_1$ is positive. Knol and Versnel showed recently that complete noise suppression can always be obtained under the above assumption of complete correlation if a suitable amount of external feedback is applied. With the help of the above theory it is shown, however, that the available power gain under those circumstances is less than unity.

621.396.645.018.424:621.397.61:621.3.088.7 2752

The Compensation for Phase Errors in Wide-Band Video Amplifiers—A. E. Brain. (*Proc. IEE* (London), Part III, vol. 97, pp. 243–251; July, 1950.) The transient response of multistage amplifiers may be improved by the insertion of several sections of bridged-T or lattice networks. A method is outlined for evaluating the phase characteristic of an amplifier with an arbitrary amplitude characteristic. Application of three suitable phase-correction circuits to a 16-stage amplifier reduced the rise time by about 33 per cent and the overshoot from over 20 per cent to less than 9 per cent.

621.396.645.094 2753
On the Problem of Distortionless Amplification of D.C. Pulses with an A.C. Amplifier—R. Gauger. (*Zeit. Angew. Phys.*, vol. 2, pp. 179–188; April 1950.) For investigation of transients in a circuit a "transfer function" is found useful. This is defined as the ratio of output to input voltage as a function of time when a step voltage is applied to the circuit; it is therefore dependent on the circuit time-constant. The transfer function is calculated for amplifiers with and without distortion correction and with up to 3 stages. The influence of the RC combinations in cathode and screen-grid circuits is considered. By use of CR or LR correcting networks the transfer function of a RC-coupled amplifier can be made practically independent of time up to half the original time constant. For pulses of duration less than this such an amplifier is suitable. The compensated amplifier has a lower minimum operating frequency and gives very little phase change at low frequencies. Distortion-free amplification can be achieved for square waves of fundamental frequency at least twice as high as the limiting frequency of the non-compensated amplifier.

621.396.645.35:621.317.755 2754
D.C. Amplifier Techniques in Oscillography—Maron. (*See* 2838.)

621.396.822:519.283 2755
Statistical Prediction of Noise—Y. W. Lee, and C. A. Stutt. (*Proc. NEC* (Chicago), vol. 5, pp. 342–365; 1949.) Pertinent results in Wiener's theory of prediction (2465) above and their application to the prediction of filtered noise are discussed. Calculations leading to the required network for prediction of such noise are given in detail. Results in the form of a simultaneous display of predictor input and output waveforms show that the theory provides a useful approach to certain communication problems.

681.142 2756
Feedback in Electrical Analogue [Impedance] Chains and Networks—P. Grivet and Y. Rocard. (*Rev. Sci.*, (Paris), vol. 87, p. 85; April and June, 1949.) The introduction of reaction into such circuits extends their mathematical application.

621.314.3† 2757
The Transductor Amplifier [Book Review]—U. Krabbe. Publishers: Ejnar Munkesgaard, Copenhagen, 1949, 176 pp., Dan. kr. 22. Obtainable from Bonniers, 605 Madison Ave, New York 22, at $5.50. (*Electronics*, vol. 23, p. 132; August, 1950.) "An excellent treatise on saturable-core reactors and their applications. The author, a competent mathematician, has shown rare ability in expressing equations in words prior to resorting to formulas . . . It . . . will constitute an invaluable addition to any engineering library."

621.318.42 2758
The Theory and Design of Inductance Coils. [Book Review]—Publishers: Macdonald, London, 180 pp., 18s. (*Electrician*, vol. 145, p. 425; August 18, 1950.) "The object of this book is to explain, in general terms, the underlying theory on which the design of inductance coils is based, and then to show how the theory can be simplified by the use of certain approximations and to what extent they are justified . . . It is very well produced, carries a small, but useful, bibliography and should be a valuable reference work."

GENERAL PHYSICS

535.222 2759
A Measurement of the Velocity of Light—R. A. Houstoun. (*Proc. Roy. Soc. A*, vol. 63, Part 1, pp. 95–104; 1949–1950.) Full paper. Short account abstracted in 1896 of September.

535.314 2760
Improvement of the Optical Schlieren Method by Minimum Ray Indication—H. Wolter. (*Ann. Phys. Lpz.*, vol. 7, pp. 182–192; April 1, 1950.)

537.311.33:621.314.634 2761
Experimental Examination of Rectifier Theory as Applied to the Selenium Rectifier—Henkels. (*See* 2798.)

537.312.8:[539.23+669-426 2762
The Conductivity of Thin Wires in a Magnetic Field.—R. G. Chambers. (*Proc. Roy. Soc. A*, vol. 202, pp. 378–394; August 7, 1950.) A thin metal wire or film has a lower electrical conductivity than the bulk material if the thickness is comparable with the electronic mean free path. This problem is examined from the kinetic-theory standpoint and the conclusions are applied to the case of a thin wire in an axial magnetic field. Experimental results are given which agree with the theoretical predictions.

537.525:[537.542.2+536.49 2763
The Role of Cathode Temperature in the Glow Discharge—H. Jacobs and J. Martin. (*Jour. Appl. Phys.*, vol. 21, pp. 681–685; July, 1950.) A study of the effect of the temperature of oxide-coated cathodes on cold-cathode glow discharges in neon, argon and neon/argon and Hg-vapor/argon mixtures.

537.562:538.561 2764
Unstable Oscillations in an Electron Gas—K. G. Malmfors. (*Ark. Fys.*, vol. 1, Part 6, pp. 569–578; March 15, 1950. In English.) An analytical treatment of the problem of electron beams in a magnetic field. At high densities an appreciable part of the electron current is collected by negative electrodes and noise level is high, indicating the existence of an energy-interchange mechanism other than ordinary collision; unstable oscillations exist at all frequencies. Such effects may afford a possible explanation of solar and galactic noise.

538.31:538.214:621.396.677 2765
The Effective Permeability of an Array of Thin Conducting Disks—G. Estrin. (*Jour. Appl. Phys.*, vol. 21, pp. 667–670; July, 1950.) "When an alternating magnetic field is parallel to the disk faces, the field is undisturbed and the relative permeability coefficient is unity. When the alternating magnetic field is normal to the disk faces, circulating currents are induced on them. The boundary-value problem of determining the current distribution on a single perfectly conducting disk is carried out in detail for the case where the disk diameter is small compared to the wave-length. This current distribution is found to be representable by a magnetic dipole. If the disks in an array are far enough apart to neglect interaction, a simple summation of the dipole moments shows the array to have a diamagnetic susceptibility in the direction normal to the disk faces. Combining this result with an expression for the dielectric coefficient, which was developed earlier by Kock [2176 of 1948] the constants of the anisotropic array are completely specified."

538.52/.53 2766
Self and Mutual Inductance of a Spherical Metal Shell and of an Endless Solenoid—A. Colombani. (*Compt. Rend. Acad. Sci.*, (Paris, vol. 230, pp. 2158–2160; June 19, 1950.) Simple formulas, which may be of practical importance in high-frequency work, are derived.

538.566:535.421 2767
Rigorous Theory of the Diffraction of Plane Electromagnetic Waves at a Perfectly Conducting Circular Disk and at the Circular Aperture in a Perfectly Conducting Plane Screen—J. Meixner and W. Andrejewski. (*Ann. Phys. Lpz.*, vol. 7, pp. 157–168; April 1, 1950.) A rigorous solution which satisfies the radiation and boundary conditions and facilities numerical calculation is obtained by representing the em field by means of the Hertzian vector potential and developing the expression for the wave in the form of spheroidal functions. The field and the induced-current distribution in the diffracting disk are fully investigated for the particular case of relatively long waves. The complementary problem of diffraction a a circular aperture in a screen of infinite extent may be treated similarly, by virtue of the validity of the generalized Babinet principle.

538.566:537.562 2768
Electro-Magneto-Ionic Waves—V. A. Bailey and K. Landecker. (*Nature* (London), vol. 166, pp. 259–261; August 12, 1950.) Experiments have been made, using gas-discharge tubes subjected to magnetic fields to test the theory that discrete frequency bands exist in which em waves can grow in an ionized medium, developing strong em noise from initially small random perturbations. Various gases, pressures and electrode arrangements were used. For fields$\geqq$100 gauss applied along the tube the expected bands always appeared; some observed noise intensities are shown graphically. From the positions of the bands conclusions are drawn regarding the details of wave propagation. Observations were also made on a thyratron with magnetic field applied transversely. The experiments demonstrate the value of the theory and supply a rough model of a sunspot emitter of enhanced solar noise. See also 1665 of July (Bailey and Roberts), 2785 and 3406 of 1949 (Bailey).

548.232:538.221 2769
Oriented Crystals: their Growth and Their Effects on Magnetic Properties—W. Morrill. (*Gen. Elec. Rev*, vol. 53, pp. 16–21; August, 1950.) Practical use of the anisotropic properties of metals is well advanced and the controlled growth of oriented crystals has produced exceptional magnetic properties in certain commercial materials. Study of crystal orientation and growth is proceeding in many laboratories and it is hoped that eventually any degree of preferred crystal orientation in any magnetic material will be commercially practicable.

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.2/.8:538.12 2770
The Hydromagnetic Equations—W. M. Elsasser. (*Phys. Rev.*, vol. 79, p. 183; July 1, 1950.) Using "Maxwellian" electrodynamics equations analogous to the hydrodynamic equations are derived for the currents and associated magnetic fields carried by cosmic fluids. These phenomena are of interest for solar, stellar and sunspot magnetism, geomagnetism, magnetic fields in stellar atmospheres and in interstellar space and the related problem of galactic radio noise.

523.841.2:538.12 2771
Stellar Magnetic Fields—H. W. Babock. (*Nature* (London), vol. 166, pp. 249–251; August 12, 1950.) An account of observations of the magnetic fields of certain variable stars. The star HD 125248 appears to be a magnetic dipole oscillator, with a fundamental frequency 1.25 microcycles/sec, radiating about 10^{12} kw on both fundamental and secondary harmonic.

537.562:538.566 2772
Electro-Magneto-Ionic Waves.—Bailey and Landecker. (*See* 2768.)

551.51:535.326]:621.396.11 2773
Determination of Modified Index-of-Refraction over the Gulf of Mexico from Radio Data—A. W. Straiton and A. H. LaGrone. (*Jour. Appl. Phys.*, vol. 21, pp. 661–666; July, 1950.) Measurements of signal strength and phase of 3.2-cm waves for a 26.5-mile over-sea path were made during June and July, 1949. The radio data are analysed, using Macfarlanes theory (3487 of 1948) to give the modified refractive-index curves, which are compared with those deduced from meteorological observations.

551.510.535+523.5 2774
A Comparison of Meteor Activity with Occurrence of Sporadic E Reflections—V. C. Pineo. (*Science*, vol. 112, pp. 50–51; July 14, 1950.) Previously presented evidence (*ibid.*, vol. 110, p. 280; 1949.) that the echo from a meteor trail differs in character from a sporadic-*E* reflection is supported by a statistical study of continuous observations made at the National Bureau of Standards from November, 1, 1948 to April 30, 1949. Sporadic-*E* is regarded as long-duration abnormality, as distinct from ionization bursts, and extreme care was taken to ensure that only reflections of true sporadic-*E* type were counted. Monthly average values of (*a*) hourly rate of meteor reflections, and (*b*) percentage of time of occurrence of sporadic-*E* reflections, show characteristic maxima at about 0600 EST and midday respectively. A scatter diagram gives no indication of correlation between the two quantities. Day-to-day curves for the month of January show no similarity. The data thus indicate that sporadic-*E* reflections are unrelated to meteor phenomena, at least to those detectable on 27.2 Mc.

551.510.535 2775
Data on the F_2 Layer of the Ionosphere [analyzed] according to the Parabola Model—E. Theissen. (*Naturewiss.* vol. 37, pp. 334–335; July, 1950.) Diurnal, seasonal and long-term ionospheric variations observed at two German stations are examined.

551.594.51 2776
On the Origin of Ten Centimeter Radiation from the Polar Aurora—P. A. Forsyth, W. Petrie, and B. W. Currie. (*Canad. Jour. Res.*, vol. 28, pp. 324–335; May, 1950.) Short-lived bursts of 10-cm radiation from auroral displays have been received by radar equipment. The sources of continuous radiation from a partially ionized medium are briefly discussed. From a knowledge of the constants of the equipment used it is deduced that the power density at the receiver is at least 2×10^{-10} w/m^2, and it seems that the most likely source of this radiation is a plasma oscillation of the ionized volume associated with the auroral display. If this is so, the electron density in localized regions must be of the order of $10^{11}/cm^3$.

521.030:537.5 2777
Cosmical Electrodynamics [Book Review]—H. Alfvén. Publishers: Clarendon Press, Oxford and Oxford University Press, London, 1950, 238 pp., 25s. (*Nature* (London), vol. 166, p. 243; August 12, 1950.) "A short general survey is followed by three chapters discussing the motion of charged particles in a magnetic field, electric discharges, and the magneto-hydrodynamic waves which Alfvén himself first discovered. The ideas developed in these three chapters are then applied in a further three chapters to solar physics (sunspots, chromospheric and coronal temperatures, prominences, etc.), magnetic storms and auroras, and cosmic radiation."

LOCATION AND AIDS TO NAVIGATION

621.396.9 2778
Thunderstorm Tracks by Radar—R. F. Jones. (*Weather* (London), vol. 5, pp. 224–225; June, 1950.) Radar photographs taken near Dunstable of thunderstorms at Evesham and Birmingham on July 13, 1949 are shown and discussed.

621.396.9:531.761 2779
Theoretical Limit to Time-Difference Measurements—Richman. (*See* 2824.)

621.396.933 2780
Traffic-Handling Capacity of Paired-Pulse Coding for 100-Channel Distance-Measuring Equipment (DME)—C. J. Hirsch. (*Proc. NEC* (Chicago), vol. 5, pp. 366–386; 1949.) See 1918 of September.

621.396.933 2781
Radio Aids to Navigation at the Ministro Pistarini Airport [Buenos Aires]—P. N. Guzzi. (*Rev. Telegr.* (Buenos Aires), vol. 37, pp. 307–312; June, 1949.) The aids provided, chosen to conform to ICAO recommendations, will include GCA and an instrument landing system.

621.396.933 2782
Instrumental Landing System for Aircraft—A. N. Bhattacharyya. (*Indian Jour. Phys.*, vol. 23, pp. 13–18; January, 1949.) General discussion of a system using the interference of ultra-high-frequency waves radiated from two antennas excited in the same phase with a common frequency.

621.396.933 2783
Microwave Radio Blind-Landing Systems for Aircraft—A. N. Bhattacharyya. (*Indian Jour. Phys.*, vol. 23, pp. 88–92; February, 1949.) Two sharply defined beams rotating in a plane inclined to the earth's surface at the glide angle are produced respectively by two horn antennas rotating in opposite directions. The beams are synchronized to intersect in the vertical plane midway between the antennas thus defining a glide path. Operating frequency is of the order of 20 kMc.

MATERIALS AND SUBSIDIARY TECHNIQUES

531.788.12 2784
A Rotary McLeod Gauge—M. Axelbank. (*Rev. Sci. Instr.*, vol. 21, pp. 511–513; June, 1950.) The new model described is improved in respect of portability, robustness and ease of operation.

531.788.7 2785
Extension of the Low-Pressure Range of the Ionization Gauge—R. T. Beyard and D. Alpert. (*Rev. Sci. Instr.*, vol. 21, pp. 571–572; June, 1950.) The new model described has been used to measure pressures of the order of 10^{-10} mm Hg.

538.221:546.56.723.722 2786
Magnetic Properties and Structure of the Quadratic Phase of Ferrite of Copper—L. Weil, F. Bertaut, and L. Bochirol. (*Jour. Phys. Radium*, vol. 11, pp. 208–212; May, 1950.)

538.221:621.317.411.029.5 2787
Determination of the Apparent Permeability and Q Factor of a Magnetic Powder at High Frequency—A. Colombani. (*Jour. Phys. Radium*, vol. 11, pp. 201–207; May, 1950.) The resultant internal and external fields are first calculated for an isolated particle in a high-frequency magnetic field. The results are applied to a uniform distribution of particles within a medium. From the complex permeability found, the Q factor and flux reduction factor are easily deduced. Calculated values, dependent on frequency, conductance and grain size, are in good agreement with experimental results. See also 1172 of June.

538.221:669.231.15 2788
Magnetic Properties of Platinum-Iron Alloys: Part 2—A. Kussmann and G. von Rittberg. (*Ann. Phys., Lpz.*, vol. 7, pp. 173–101; April 1, 1950.) For alloys containing 50 to 63 per cent Pt by weight, magnetostriction effects are the highest yet observed in ferromagnetic materials. Optimum properties for permanent magnets are obtained when the Pt content is 70 per cent. Magnetostriction in this case is very small.

538.221:669.231.74 2789
Ferromagnetic Platinum-Manganese Alloys—M. Auwärter and A. Kussmann. (*Ann. Phys., Lpz.*, vol. 7, pp. 169–172; April 1, 1950.) The ferromagnetic properties exhibited by Pt-Mn alloys containing 6 to 16 per cent Mn by weight are attributed to the ordered arrangement of the atoms in the mixed crystals as Pt_3Mn. Magnetic-saturation and thermal-expansion curves, lattice constants and transition temperatures are given.

538.652:669.018.58 2790
Evaluation of the Magnetostrictive Properties of Hiperco—H. Sussman and S. L. Ehrlich. (*Jour. Acous. Soc. Amer.*, vol. 22, pp. 499–506; July, 1950.) A description of tests made to evaluate the suitability of the alloy as a material for transducers. The performance criteria are established, and the properties and performance of hiperco, nickel and permendur are compared. For remanence operation hiperco is satisfactory for hydrophone use, but it is inferior to the other materials for high-power underwater projection. Its performance is improved by polarizing above remanence.

546.217:621.317.335.3.029.64 2791
The Permittivity of Air at a Wavelength of 10 Centimeters—Phillips. (*See* 2827.)

546.471.61:537.311+537.323+538.632 2792
Electronic Processes in Zinc Fluoride and in the Manganese-Activated Zinc Fluoride Phosphor—J. H. Crawford, Jr, and F. E. Williams. (*Jour. Chem. Phys.*, vol. 18, pp. 775–780; June, 1950.) Measurements of the temperature dependence of electrical conductivity and thermal emf for ZnF_2 and ZnF_2-Mn, and of the Hall coefficient and rectifying power at 25°C for ZnF_2.

546.472.21:535.37 2793
The Poisoning of Cathodoluminescence in Silver-Activated Cubic Zinc Sulfide—S. Larach. (*Jour. Chem. Phys.*, vol. 18, p. 896; June, 1950.) Small amounts of Co, Fe or Ni sulphates were crystallized together with the ZnS-Ag phosphor. The poisoning effect was about the same for all three impurities. Cathode rays were used for excitation.

548.0:537 2794
Ferroelectric Crystals—B. Matthias. (*Helv. Phys. Acta*, vol. 23, pp. 167–170; February 3, 1950. In German.) Fundamental research carried out at the E. T. H., Zürich, is described briefly. The possibility of finding other ferroelectric crystals isomorphic with $BaTiO_3$ is investigated.

549.514.51:548.523 2795
Growing Large Quartz Crystals—A. C. Walker and E. Buehler. (*Indust. Eng. Chem.*, vol. 42, pp. 1369–1375; July, 1950.) Full paper. Summary abstracted in 411 of 1949.

621.3.015.5:546.217 2796
A Note on Ultra-High-Frequency Gas Breakdown—W. A. Prowse. (*Proc. IEE*,

(London), Part III, vol. 97, pp. 253–254; July, 1950.) Some results obtained by Pim (2246 of 1949) show breakdown voltages which increase as the gap width is reduced. An explanation is here given as to why the spark, under such conditions, does not simply transfer to a point of greater gap width.

621.3.087.45 2797
Closed-Cycle Recording Oscillographs—B. Ciscel and R. Ruhland. (*Proc. NEC*, vol. 5, pp. 4–10; 1949.) Review of available equipment and description of an 8-channel pen recorder, with servo-moter pen drive, for use in flight tests.

621.314.634:537.311.33 2798
Experimental Examination of Rectifier Theory as Applied to the Selenium Rectifier—H. W. Henkels. (*Proc. NEC* (Chicago), vol. 5, pp. 23—39; 1949.) Recent work at the University of Pennsylvania on the correlation of rectifier theory with experiment is examined. The variables in Schottky's theory are treated individually. The electrical properties of single crystals, as well as microcrystalline specimens, are examined in their relation to the Se rectifier. To explain bulk properties, a model of microcrystalline selenium must possess layers of high resistance at crystal grain boundaries, and surface layers on the crystallites of quite low resistance.

621.315.592†:539.23 2799
Concerning the Theory of Photoconductivity in Infra-red-Sensitive Semiconducting Films—E. S. Rittner. (*Science*, vol. 111, pp. 685–688; June 23, 1950) Critical discussion of various theories, with a more general explanation of the effects observed in such films which avoids the difficulty of the exact balancing of impurities.

621.315.612.4:546.431.82 2800
The Dielectric Properties of Barium Titanate—R. E. Averbukh and M. S. Kosman. (*Zh. Eksp. Teor. Fiz.*, vol. 19, pp. 965–970; November, 1949.) The dependence of the dielectric constant of $BaTiO_3$ on temperature and on field strength is investigated by a new ballistic method. The expression for the constant consists of two terms which vary differently.

621.315.612.6:537.311 2801
Electrical Conduction in Glass—P. L. Kirby. (*Brit. Jour. Appl. Phys.*, vol. 1, pp. 193–202; August, 1950.) The mechanism of electrical conduction in glass is discussed in the light of modern theories of its atomic structure. Variation of conductivity with composition is explained by reference to the valency requirements of the network atoms, and the temperature variation of conductivity is examined. The relative magnitudes of the dielectric absorption current and the true conduction current are considered, and the total loss angle is calculated for various temperatures to illustrate the transition from a dielectric to an ionic conductor.

621.315.616.7 2802
A New Dry-Type Insulation for Instrument Transformers.—R. A. Pfuntner, R. E. Franck, and F. R. D'Entremont. (*Elec. Eng.*, vol. 69, pp. 594–599; July, 1950.) Butyl, a rubber-like material, can be moulded completely round core and coils; its dielectric properties are excellent over a wide range of temperature and humidity and it is chemically stable.

621.395.625.3:681.6 2803
A New Magnetic Record Duplicating Process—M. Camras. (*Proc. NEC* (Chicago), vol. 5, pp. 258–261; 1949) A rapid contact-printing process in which the blank is held against a master tape while the two are subjected to a high-frequency magnetic field. See also 2804 below (Herr).

621.395.625.3:681.6 2804
Duplication of Magnetic Tape Recordings by Contact Printing—R. Herr. (*Proc. NEC* (Chicago), vol. 5, pp. 262–268; 1949.) Discussion of a method identical in principle with that noted in 2803 above, and brief description of practical equipment. The method is not limited to tape records, but can be applied to records on disks, drums, etc. It does not seem applicable to the duplication of records on wire.

621.946.148.12 2805
High-Voltage and Electrolytic Drilling of Diamond Dies—(*Machinery* (London) vol. 76, No. 1961, pp. 743–744; May 25, 1950.) Short account of method noted in 3944 of 1947.

666.1.037.5:539.319 2806
Stresses in Glass/Metal Seals: Part 1—The Cylindrical Seal—E. W. Martin. (*Jour. Amer. Ceram. Soc.*, vol. 33, pp. 224 229; July 1, 1950.) Consideration of viscous flow during cooling of a beaded wire seal following annealing treatment leads to a modification of the theory of Hull and Burger (1184 of 1935); good agreement is then obtained between theoretical and experimental values of stress in beaded wire seals. Cylindrical seals with the metal outside are also considered. The expansion necessary for the best match depends on the geometry of the seal. In general, metal glass seals should be annealed at a temperature above that used for the glass alone.

537.228.1:548.0 2807
Piezoelectric Crystals and their Application to Ultrasonics [Book Review]—W. P. Mason. Publishers: D. Van Nostrand, New York, 508 pp., \$7.50. (*Jour. Acous. Soc. Amer.*, vol. 22, pp. 519–520; July, 1950.)

MATHEMATICS

519.242:621.396.1 2808
An Extension of Wiener's Theory of Prediction—L. A. Zadeh and J. R. Ragazzini. (*Jour. Appl. Phys.*, vol. 21, pp. 645 655; July, 1950.) The signal (message) component of the given time series is assumed to consist of two parts, (*a*) a non-random function of time which is representable as a polynomial of degree not greater than a specified number n and about which no information other than n is available; and (*b*) a stationary random function of time which is described statistically by a given correlation function. (In Wiener's theory, the signal may not contain a non-random part except when such a part is a known function of time.)

The impulsive response of the predictor or, in other words, the weighting function used in the process of prediction is required to vanish outside of a specified time interval $0 \leq t \leq T$. (In Wiener's theory T is assumed to be infinite.)

The theory developed in this paper is applicable to a broader and more practical class of problems than that covered in Wiener's theory. As in Wiener's theory, the determination of the optimum predictor reduces to the solution of an integral equation which, however, is a modified form of the Wiener-Hopf equation. A simple method of solution of the equation is developed. This method can also be applied with advantage to the solution of the particular case considered by Wiener. The use of the theory is illustrated by several examples of practical interest." See also 2465 above.

681.142 2809
Linear Electronic Analog Computer Design—C. A. Meneley and C. D. Morrill. (*Proc. NEC* (Chicago), vol. 5, pp. 48–63; 1949.) Discussion of problems of design and a description of a complete computer with power supplies, housed in a single 6 ft. × 19 in. cabinet.

681.142 2810
Feedback in Electrical Analogue [impedance] Chains and Networks—P. Grivet and Y. Rocard. (*Rev. Sci.*, (Paris) vol. 87, p. 85; April-June, 1949.) The introduction of feedback in such circuits extends their mathematical application.

681.142 2811
An Electronic Integral-Transform Computer and the Practical Solution of Integral Equations—H. Wallman. (*Jour. Frank. Inst.*, vol. 250, pp. 45–61; July, 1950.) Description of the principle and discussion of the applications of a proposed instrument performing computations in about 0.1 sec and presenting results graphically on a cathode-ray tube screen.

681.142:512.25 2812
A Computer for Solving Secular Equations—J. F. Storm. (*Proc. NEC* (Chicago), vol. 5, pp. 98–106; 1949.) A manually operated analogue computer for obtaining the real roots of a 3-by-3 set of secular equations. Modifications required for automatic operation are discussed.

681.142:621.314.3† 2813
Magnetic Amplifier Studies on the Analog Computer—Harder, Hamilton, Aldrich, Carleton, and McClure. (*See* 2731.)

681.142:621.389 2814
The Photoformer in Anacom Calculations—H. W. Schultz, J. F. Calvert, and E. L. Buell (*Proc. NEC* (Chicago), vol. 5, pp. 40–47; 1949.) Description of a device for generating a wide variety of functions by making a cathode-ray beam follow the edge of an appropriate mask, with discussion of its use as a nonlinear element in an analogue computer.

517.31/.36+517.7](083.81) 2815
Integraltafel. Erster Teil: Unbestimmte Integrale [Book Review]—W. Gröbner and N. Hofreiter. Publishers: Springer-Verlag, Vienna, 1949, 166 pp. \$5.40. (*Quart. Appl. Math.*, vol. 7, p. 474; January, 1950.) "This table of indefinite integrals appears to be more complete than others generally available. There are three sections. . . entitled Rational Integrands . . . , and Transcendental Integrands . . ." Part 2, on definite integrals, is in preparation.

517.512.2+517.942.82 2816
Fourier Methods [Book Review]—P. Franklin. Publishers: McGraw-Hill Book Co., New York, 1949, 289 pp., \$4.00. (*Jour. Frank. Inst.*, vol. 249, pp. 258–259; March, 1950.) This is a book written for students. "The author broadly interprets Fourier methods as any analysis or synthesis of functions by a linear process applied to sines, cosines, or to complex exponentials . . . [He] has successfully treated the subject of Fourier series and transforms and Laplace transforms in an introductory manner which . . . is adequate for many practical problems."

517.564.2(083.5) 2817
Tables of Inverse Hyperbolic Functions [Book Review]—Computation Laboratory, Harvard University. Publishers: Harvard University Press, Cambridge, Mass., 1949, 290 pp., \$10.00. (*Quart. Appl. Math.*, vol. 7, p. 475; January, 1950.) First and second differences are given, and the functions are tabulated to 9 decimal places.

517.564.3(083.5) 2818
Tables of Bessel Functions of Fractional Order: Vol. 2 [Book Review]—Computation Laboratory, National Bureau of Standards. Publishers: Columbia University Press, New York, 1949, 365 pp., \$10.00. (*Quart. Appl. Math.*, vol. 7, p. 475; January, 1950.) $I_\nu(x)$ is tabulated for $\nu = \pm\frac{1}{4}, \pm\frac{1}{3}, \pm\frac{2}{3}, \pm\frac{3}{4}$, x ranging

from 0 to 13 for the negative values of ν and from 0 to 25 for the positive values of ν. $e^{-x} I_\nu(x)$ is tabulated for the same values of ν and for x ranging from 25 to 30,000. Functions are tabulated to 10 decimal places or 10 significant figures. Auxiliary tables facilitate interpolation in the x and ν directions.

517.564.3(083.5) 2819

Tables of the Bessel Functions of the First Kind of Orders Fifty-Two through Sixty-Three [Book Review]—Computation Laboratory, Harvard University. Publishers: Harvard University Press, Cambridge, Mass., 1949, 544 pp., $8.00. (*Quart. Appl. Math.*, vol. 7, p. 479; January, 1950.) $J_{52}(x)$, $J_{53}(x)$, ... $J_{63}(x)$ are tabulated to 10 decimal places for values of x ranging from 0 to 100 in steps of 0.01.

517.7 2820

Anwendung der elliptischen Funktionen in Physik und Technik [Book Review]—F. Oberhettinger and W. Magnus. Publishers: Springer, Berlin, 1949, 126 pp., paper cover, 15.60 DM, bound, 18.30 DM. (*Naturwiss*, vol. 37, p. 237; May, 1950.) Includes a series of examples of two-dimensional problems in electrostatics and hydromechanics, particularly field calculations, and current flow in channels of rectangular or elliptical cross-section, and Tchebycheff approximations in filter circuit theory.

517.9 2821

Partial Differential Equations in Physics [Book Review]—A. Sommerfeld. Publishers: Academic Press, New York, 1949, 335 pp., $5.80. (*Science*, vol. 111, p. 414; April 21, 1950.) A translation by E. G. Straus of the sixth volume of Somerfeld's "Lectures on Theoretical Physics." "The last chapter deals with the propagation of radio waves and serves as an illustration of many of the general methods developed in earlier chapters. The chief merit of the book lies in its skilful handling of complex problems, by the use of a minimum of mathematical formalism and a maximum of physical intuition."

518.12 2822

Numerical Calculus [Book Review]—W. E. Milne. Publishers: Princeton University Press, Princeton, N. J., 1949, 393 pp., $3.75. (*Quart. Appl. Math.*, vol. 7, p. 478–479; January, 1950.) An elementary presentation, covering approximations, interpolation, finite differences, numerical integration and curve fitting.

MEASUREMENTS AND TEST GEAR

531.761:621.387.424† 2823

A Direct-Reading Device for Measuring Dead Time and Recovery Time of Geiger Counters—Epprecht. (*See* 2864.)

531.761:621.396.9 2824

Theoretical Limit to Time-Difference Measurements—D. Richman. (*Proc. NEC* (Chicago), vol. 5, pp. 203–210; 1949.) Theoretical relations are derived between the accuracy with which a signal may be located in time; and the various factors which determine the accuracy. These are (*a*) signal noise ratio, (*b*) modulation bandwidth, (*c*) signal duration, (*d*) signal frequency. The relations can be used to compute the signal noise ratio required in systems of prescribed bandwidth, signal duration, and accuracy.

621.3.089.6:621.396.615.085.41 2825

Automatic Calibration of Oscillator Scales—W. J. Means and T. Slonczewski. (*Proc. NEC* (Chicago), vol. 5, pp. 217–221; 1949.) Long frequency scales used in heterodyne oscillators are calibrated by recording photographically on a strip of motion-picture film the image of a master scale which continuously indicates the instantaneous frequency of the oscillator.

621.317.31/.32:621.396.645 2826

Notes on Voltage, Current and Charge Measurements by Means of Valve Amplifiers—W. Böer. (*Ann. Phys., Lpz.*, vol. 7, pp. 193–208; April 1, 1950.) Two parameters are defined by means of which different types of apparatus can be compared: (*a*) electrical resolving power, which is a measure of the least difference detectable between two currents of 1-sec duration; (*b*) pulse sensitivity. Estimates are made of the disturbing effect of fluctuations originating in batteries, resistors and valves, and noise effects in grounded-grid and free-grid valves are considered. Practical measurement limits for voltage, current and charge are deduced. Some fifty references are given.

621.317.335.3.029.64†:546.217 2827

The Permittivity of Air at a Wavelength of 10 Centimeters—W. E. Phillips. (Proc. I.R.E., vol. 38, pp. 786–790; July, 1950.) Measurements of the permittivity of air as a function of water-vapor content, at atmospheric pressure and temperature, support the results of previous workers regarding the important effect of atmospheric water-vapor content on the refraction of ultra-high-frequency waves. Measurements on dry air and water vapor at reduced pressure are also recorded. Permittivity is determined by comparing the wavelengths of standing waves in a cylindrical cavity resonator when evacuated to a pressure of 0.01 mm Hg and when containing the air sample under test. The following values for permittivity were obtained: dry air at 759.09 mm Hg and 25.5°C, 1.0005548; dry air at reduced pressure and 22°C, 1.000393, at 555.48 mm Hg and 1.000129, at 180.08 mm Hg; moist air, 1.000806 at 752.45 mm Hg, 22°C and 100 per cent humidity, falling to 1.000668 at 756.45 mm Hg, 19°C and 55.7 per cent humidity.

621.317.361 2828

On the Problem of Unequivocal Frequency Measurement by Comparison with Fixed Standard Frequencies—H. M. Schmidt. (*Zeit. Angew. Phys.*, vol. 2, pp. 219–223; May, 1950.) In the method discussed the unknown frequency f_x is heterodyned with (*a*) a suitable harmonic nf_0 of the standard frequency f_0, and (*b*) a second standard-frequency source f_0 with a known phase displacement ϕ. The phase difference of the difference frequencies produced is $fn\phi$ according as f_x is higher or lower than nf_0. The number n is given by the ratio of the phase angle for the difference frequencies to that for the fundamentals.

621.317.361:621.396.611.21 2829

Crystal Resonators as Frequency Substandards—F. J. M. Laver. (*Proc. IEE* (London), Part III, vol. 97, p. 252; July, 1950.) Discussion on 1453 of July.

621.317.42 2830

Notes on the Theory and Practice of Magnetic Field-Strength Comparators of the Förster Type—M. Wurm. (*Zeit. Angew. Phys.*, vol. 2, pp. 210–219; May, 1950.) Discussion of the principle of and design improvements for the premagnetized coil-type meter. See also 1470 of 1941 (Förster).

621.317.714.011.6 2831

The Measurement of the Time Constant of a Critically Damped Meter—S. F. Pearce. (*Jour. Sci. Instr.*, vol. 27, pp. 202–203; July, 1950.) The performance of critically damped meters, such as are required as the final indicating instrument in a receiver used for the measurement of radio interference, is analyzed and a simple method is described for measurement of the time constant.

621.317.714.029.62 2832

Electrodynamic Ammeter for Very High Frequencies—(*Tech. Bull. Nat. Bur. Stand.*, vol. 34, pp. 103–104; July, 1950.) Short description of an instrument developed at the National Bureau of Standards by M. Solow. It consists essentially of a coaxial transmission line with a copper wire ring about 1 cm in diameter suspended between the inner and outer conductors by a quartz fibre. When current flows in the line a torque is exerted on the ring and its value is indicated optically. The instrument is calibrated by measurements at both 300 Mc and 150 Mc.

621.317.729:621.396.677 2833

Electrolytic-Tank Measurements for Microwave Metallic Delay-Lens Media—S. B. Cohn. (*Jour. Appl. Phys.*, vol. 21, pp. 674–680; July, 1950.) The low-frequency index of refraction of a delay-lens medium can be calculated from electrolyte-tank measurements on single elements. The proximity between adjacent elements is taken into account. Apparatus and method are described and results are tabulated for three types of delay-lens structure.

621.317.73 2834

Admittance Analyzer—W. B. Bernard. (*Electronics*, vol. 23, pp. 107–109; August, 1950.) The admittance to be measured is connected across a tuned circuit which is then retuned; the change of capacitance to restore resonance gives the unknown susceptance, and the conductance is calculated from $G=(E/e-1)/R$, where E is the voltage across the retuned circuit and a known resistance R in series with it, and e is the voltage across the retuned circuit alone. Resistance range was found to be 10 Ω to 1 MΩ at frequencies up to 1 Mc. At higher frequencies the upper limit is $1/f$ MΩ, where f is in Mc. A detailed circuit diagram is given of an instrument which has proved very suitable for antenna measurements on site.

621.317.73.029.62/.63 2835

Discontinuities in Concentric-Line Impedance-Measuring Apparatus—M. H. Oliver. (*Proc. IEE* (London), Part III, vol. 97, p. 242; July, 1950.) Discussion on 1188 of June.

621.317.73.083.5 2836

Correction Factors for Slotted Measuring Lines at Very High Frequencies—R. G. Medhurst and S. D. Pool. (*Proc. IEE* (London), Part III, vol. 97, pp. 223–230; July, 1950.) Errors due to mechanical irregularities usually have a repeatable effect. A correction factor varying with the position along the line can be derived. The initial determination is lengthy but the result is a multiplying factor that can be tabulated.

621.317.733:621.392.43.029.62 2837

A V.H.F. Match Meter—P. G. Sulzer. (*TV Eng.*, vol. 1, pp. 4–6; July, 1950.) The meter includes two bridges, and when connected between a low-power radio-frequency source (10–250 Mc) and an antenna or transmission line it indicates the magnitude of the reflection coefficient. One bridge is used for unbalanced systems, the other for balanced systems, the reference impedances being respectively 52 Ω and 300 Ω. The voltmeters reading the input and null voltages consist of crystal diodes with a switched dc microammeter. Calibration is effected either by comparison with a voltmeter of known accuracy or by connecting selected high-frequency resistors across the test terminals.

621.317.755:621.396.645.35 2838

D.C. Amplifier Techniques in Oscillography—M. Maron. (*Proc. NEC* (Chicago), vol. 5, pp. 11–16; 1949.) Design problems are discussed, and a description is given of a dc amplifier, developed as a signal amplifier for a cro. Auxiliary circuits, including time bases, are described. Typical applications of the dc amplifier in oscillography are outlined.

621.317.763.029.64:621.396.611.4 2839

A 10-cm Mechanically Swept Spectrometer—P. Andrews. (*Proc. IEE* (London), Part III, vol. 97, pp. 260–261; July, 1950.) Discussion on 2855 of 1949. An instrument for the same frequency, but with an electronic sweep system, is described by P. Bramham.

621.317.79:621.3.018.78† 2840

An Intermodulation Analyzer for Audio Systems—R. S. Fine. (*Audio Eng.*, vol. 34, pp. 11–13, 43, July, 1950.) A description, with detailed circuit diagram, of an instrument for measurement of intermodulation distortion. It is particularly useful for assessing the quality of amplifiers and phonograph pickups.

621.317.79:621.396.67 2841

The Electronically Driven Ripple-Tank as an Aid to Phase-Front Visualization—A. H. Schooley. (*Proc. NEC* (Chicago), vol. 5, pp. 303–314; 1949.) A detailed account of equipment noted in 1979 of September, with numerous photographs of typical patterns.

621.317.799†:621.397.5 2842

Inexpensive Picture Generator—J. R. Popkin-Clurman. (*Electronics*, vol. 23, pp. 102–106, August, 1950.) Light from the raster of a television receiver is transmitted through a transparent test pattern and picked up by a multiplier photocell whose output is amplified and corrected for cathode-ray tube phosphor decay. Video phase splitting allows positive or negative transparencies to be used. Blanking pulses are added in a mixer whose output is clipped and provides the composite video test-pattern signals, which are suitable for feeding the video section of a television receiver if synchronizing arrangements are available. A separate sweep circuit for providing raster and blanking pulses is described, with detailed diagrams.

621.396.662.029.64 2843

Microwave Attenuators for Powers up to 1000 Watts—H. J. Carlin and F. N. Torgow. (*Proc. I.R.E.*, vol. 38, pp. 777–780, July, 1950.) A broad band attenuator is described which reduces input powers by a fixed ratio to a low level measurable by a bolometer. The device is a combination of three units (*a*) a coaxial line attenuator whose axial conductor penetrates transversely into the main power-carrying coaxial line; this operates on a capacitance divider principle; (*b*) a metallized-glass coaxial attenuator (348 of 1949) for matching (*a*) to the test line and for equalizing its attenuation with respect to frequency; and (*c*) a tapered dielectric coaxial load in the main line. Two sets of equipment cover the band 1–10 kMc.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

534.321.9:539.32 2844

Ultrasonic Measurement Techniques Applicable to Small Solid Specimens—H. J. McSkimin. (*Jour. Acous. Soc. Amer.*, vol. 22, pp. 413–418, July, 1950.) A description of techniques for the measurement of velocity of propagation and attenuation by phase-comparison methods using either longitudinal or transverse waves. One is a resonance technique, using a pulse input and displaying the addition of in-phase multiple reflections from within the specimen. A more precise technique, using circuit-wave oscillations gated by dc pulses, depends on the cancellation of any order of multiple reflection by a delayed signal derived from the input. The phase shifts at reflecting interfaces may be independently determined. Derivations of the principal formulas used are given and the precautions necessary in the use of polystyrene seals and fused-silica supporting rods are described.

534.321.9:620.179.1 2845

Ultrasonics and Their Use for Non-Destructive Testing of Materials—N. G. Neuweiler. (*Microtecnic* (Lausanne), vol. 4, pp. 37–44 and 60–66; January-February, and March-April, 1950.) Illustrated description of the principles, operation and applications of a flaw detector.

534.321.9:621.398:535.88 2846

Supersonic Control of a Lantern-Slide Projector—S. G. Lutz and G. Rand. (*Proc. NEC* (Chicago), vol. 5, pp. 477–481, 1949.) Equipment is described which enables a lecturer to operate the slide-changing device on a projector by means of a small ultrasonic whistle concealed in a pocket.

535.214.4:535.61-15 2847

The Diaphragm Radiometer—P. E. Weber. (*Optik*, vol. 6, pp. 152–161, March, 1950.) A description is given of an infra-red radiation receiver whose operation is based on the kinetic effect in gases. Thermally modulated radiation is incident on a diaphragm forming one closure of a gas chamber, and the resulting oscillations of the diaphragm produce capacitance variations in one arm of a tuned high-frequency bridge. Using a modulation frequency of 100 cps, radiated power as low as 1.2×10^{-7} w/cm² can be measured, the high-frequency voltage delivered being then 10 μv. Greater sensitivity can be attained by exposing the diaphragm to sound of a frequency which is a multiple of the modulation frequency.

621.3.087.6:534.232:534.321.9 2848

Application of Supersonic Energy to High Speed Electronic Recording—Dana and Van Meter. (*Proc. NEC* (Chicago), vol. 5, pp. 473–476, 1949.) See 1561 of August.

621.316.72:537.533 2849

Automatic Regulation of Thermionic Emission—W. Steckelmacher and S. van der Meer. (*Jour. Sci. Instr.*, vol. 27, pp. 189–191, July, 1950.) Continuous control for large changes of emission conditions, such as occur in continuously pumped X-ray tubes or ionization vacuum gauges, is effected by using the change of emission current to develop a correction voltage which is applied, after amplification, to a pair of valves whose anode currents govern the heating current for the electron source. A phase shift network in the feedback chain prevents the oscillations which sometimes occur when controlling massive filaments.

621.317.083.7 2850

Matrix Telemetering System—N. R. Best. (*Electronics*, vol. 23, pp. 82–85, August, 1950.) 30 PTM channels are superimposed on a 1025-Mc carrier with peak power of 4 kw. A 10 kc oscillator in the transmitting (airborne) unit operates a 32-state counter defining 100 μs time intervals for each channel, and transmits a synchronizing pulse to an oscillator counter unit in the receiver. The signals in the various channels are displayed as time-positioned dots on a blacked-out cathode-ray tube trace and are recorded on continuously running film.

621.317.39 2851

Some Electrical Methods of Measuring Mechanical Quantities—F. J. Woodcock. (*Proc. IEE* (London), Part I, vol. 97, pp. 136–149, Discussion, pp. 149–154; July, 1950.) Full paper, including 87 references. Summary noted in 2306 of November.

621.317.39:531.717.1 2852

Thickness Gage for Moving Material—S. V. Hart and I. W. Rozian. (*Proc. NEC* (Chicago), vol. 5, pp. 83–87; 1949.) An instrument which records the thickness of any non-magnetic material within the range 0.0001–1.0 in. and detects deviations of <1 microinch from a standard. The material is inserted between primary and secondary of a split transformer, the output of which is balanced in a bridge circuit against that of a similar unit holding a standard slat. Magnetic materials can be handled by using a pair of differential transformers.

621.317.755:621.317.39 2853

Multiple-Channel Cathode-Ray Instrumentation of Non-Electrical Quantities—J. N. Van Scoyoc and G. F. Warnke. (*Proc. NEC* (Chicago), vol. 5, pp. 88–97; 1949.) Description of a 24-channel mobile unit using single-beam cathode-ray tubes whose screen patterns are photographed on continuously moving film.

621.365.55† 2854

Heating by Means of High-Frequency Fields: Part 2—Capacitive Heating—M. Stel and E. C. Witsenburg. (*Philips Tech. Rev.*, vol. 11, pp. 232–240, February, 1950.) A formula is derived for the amount of heat generated in unit time in a homogeneous dielectric. Selective heating can be produced when two different dielectrics, e.g., wood and glue, are associated. Industrial applications are discussed. Part 1, 1995 of September.

621.384.6 2855

Principle of an Ion Source for Intense Beams—C. Cassignol. (*Nature* (London), vol. 166, pp. 233–234, August 5, 1950.) The principle used is similar to that of Alfvén's trochotron (1205 of 1948), but field modifications are introduced for concentrating positive ions instead of electrons. The extracting electrode is a short cylinder coaxial with the accelerator tube, and is provided with a circumferential slit and maintained negative. An inhomogeneous magnetic field assists in focusing the ions on to the slit. Observations on this and on a simpler type of source support the theoretical assumptions.

621.384.611.1†.615.849 2856

Experiments with a 6-MeV Betatron—K. Gund and W. Paul. (*Nucleonics*, vol. 7, pp. 36–45, July, 1950.) An account is given of the development and construction of a betatron in the electromedical laboratory of Siemens-Reiniger Werke, Erlangen, Germany. Preliminary physical and biological experiments with the equipment are described, including cancer treatment in human beings.

621.384.611.2† 2857

Extraction of the Electron Beam from a 30-MeV Synchrotron—J. D. Lawson, H. F. Walford, and J. H. Aram. (*Nature* (London), vol. 166, pp. 234–235, August 5, 1950.) Electrons of energy up to 20 Mev have been extracted from the Harwell synchrotron by use of a small shunt coil carrying a pulsed current of up to 6,000 A peak, timed so that the current is a maximum when the electrons enter the shunt. No difficulty is anticipated in applying the method to 30 Mev electrons.

621.387.4† 2858

Scintillation Type Alpha-Particle Detector—A. S. Goldin, E. R. Rohrer, and R. L. Macklin. (*Rev. Sci. Instr.*, vol. 21, pp. 554–557, June, 1950.)

621.387.4† 2859

The Theory and Properties of Low Voltage Radiation Counters—J. A. Simpson, Jr. (*Rev. Sci. Instr.*, vol. 21, pp. 558–568; June, 1950.)

621.387.4†:548.0 2860
Crystal Counters—R. Hofstadter. (Proc. I.R.E., vol. 38, pp. 726–740; July, 1950.) The author's previous survey of this subject (2506 and 2507 of 1949) is extended to cover later developments such as counters using S or Ge crystals.

621.387.424† 2861
Geiger Counter for Civilian-Defense Use—H. D. LeVine, H. J. DiGiovanni, and M. R. Coe. (*Nucleonics*, vol. 6, pp. 56–59; June, 1950.) Description of a simple and relatively cheap counter. The necessary high-voltage supply is obtained from a vibrator operated by a 3-v flashlight battery.

621.387.424† 2862
A Method of Measuring Spurious Counts in Geiger-Müller Counters—D. Willard and C. G. Montgomery. (*Rev. Sci. Instr.*, vol. 21, pp. 520–521; June, 1950.)

621.387.424† 2863
The Velocity of Propagation of the Discharge in Geiger-Müller Counters—H. Saltzmann and C. G. Montgomery. (*Rev. Sci. Instr.*, vol. 21, pp. 548–549; June, 1950.)

621.387.424†:531.761 2864
A Direct-Reading Device for Measuring Dead Time and Recovery Time of Geiger Counters—G. W. Epprecht. (*Helv. Phys. Acta*, vol. 23, pp. 291–298; April 20, 1950. In German.) An RC discharge circuit is used to measure the shortest time interval between successive pulses. Some results obtained with the apparatus are shown.

621.396.9:526.9 2865
Electronic Contour Mapping—R. C. Raymond. (*Proc. NEC* (Chicago), vol. 5, pp. 211–216; 1949.) A stabilized aircraft with a pencil-beam radar set makes several thousand observations per second on the terrain over which it flies. The data are used to print a contour map. Calculations indicate that with efficient equipment contour maps covering 1,000 square miles could be printed in under an hour.

621.398 2866
The Landis & Gyr Audio-Frequency Telecontrol System—(*Bull. Tech. Suisse Romande*, vol. 76, pp. 146–148 and 162–164; June 3 and 17, 1950.) Description of a system particularly suitable for use on power lines and operating on a frequency of 475 or 725 cps. A shorter account was noted in 1744 of August.

681.142:621.385.832 2867
Coordinate Tubes for Use with Electrostatic Storage Tubes—R. S. Julian and A. L. Samuel. (*Proc. NEC* (Chicago), vol. 5, pp. 107–122; 1949.) The system uses two master tubes which separately control the horizontal and vertical displacements of the electron beams in a bank of slave tubes. Control is effected by servo amplifiers, which locate the proper memory positions from their digital address codes in terms of the mechanical positions of target plates contained within the master tubes. Two different types of tube are described, one for sequential operation, the other for a parallel address system.

621.38 2868
An Introduction to Electronics [Book Review]—J. Yarwood. Publishers: Chapman and Hall, London, 329 pp., 28s. (*Electrician*, vol. 145, p. 425; August 18, 1950.) ". . . for those physics and engineering students . . . who need an account of the subject at an intermediate standard . . . and also as a guide to lecturers."

621.38 2869
Industrial Electronics and Control [Book Review]—R. G. Kloeffler. Publishers: Chapman and Hall, London, 1949, 478 pp., 33s. (*Beama Jour.*, vol. 57, pp. 181–182; June, 1950.) ". . . written not only for the electrical engineer, but also for students of chemical and mechanical engineering who desire a knowledge of industrial electronic applications. The text is descriptive rather than mathematical and the calculus is not employed."

621.38 2870
Electronics, Principles and Applications [Book Review]—R. R. Wright. Publishers: Ronald Press, New York, 1950, 387 pp., $5.50. (*Electronics*, vol. 23, pp. 136, 138; August, 1950.) "A basic course in electronics for non-electrical engineering students."

PROPAGATION OF WAVES

538.566 2871
On the Existence of a Surface Wave in Dipole Radiation over a Plane Earth—T. Kahan and G. Eckart. (Proc. I.R.E., vol. 38, pp. 807–812; July, 1950.) See 2892 of 1949.

621.396.11 2872
Ground-Wave Propagation over an Inhomogeneous Smooth Earth. Part 2—Experimental Evidence and Practical Implications—G. Millington and G. A. Isted. (*Proc. IEE* (London), Part III, vol. 97, pp. 209–217; July, 1950. Discussion, pp. 217–222.) Theoretical considerations of Part 1 (1758 of 1949) are reviewed, which predict an increase in field strength on crossing a land-sea boundary. Further experimental results are discussed and found in agreement with theory, although not conclusive. The best conditions for obtaining such an increase in practice are analysed: a wavelength of 4 m is suitable where the distances involved are small, while 100-m wavelength is preferable where attenuation with distance is much greater over land than over sea. Measurements on these wavelengths of field strength along land-sea paths are described; the results show the predicted increase and fit the calculated curves as well as experimental conditions would allow. Some practical implications of the results are discussed, in particular with regard to the siting of transmitters near water, the possibilities of common-frequency working under ground-wave conditions, and the ground-wave coverage of medium- and long-wave navigation aids.

621.396.11 2873
The Beacon Technique as Applied to Oblique Incidence Ionosphere Propagation—J. T. deBettencourt and H. Klemperer. (Proc. I.R.E., vol. 38, pp. 791–792; July, 1950.) Experiments have been made to identify the propagation paths of pulse signals. An interrogator-responder near Boston transmitted pulses of width 100 μs and repetition rate 20/sec to a transponder in the Caribbean area 2,615 km away. Horizontal rhombic antennas, and transmitters giving 20 kw peak power at 16.08 Mc were used at both stations. Photographic records were obtained showing pulse amplitudes against go-and-return time, and go-and-return time against time of day. One-way transmission time is simply calculated from the observations and the path travelled is then identified by means of available charts.

621.396.11:[551.51:545.326 2874
Determination of Modified Index-of-Refraction over the Gulf of Mexico from Radio Data—Straiton and LaGrone. (*See* 2773.)

621.396.11:551.510.535 2875
Ray Paths of Radio Waves in the Ionosphere—H. Poeverlein. (*Zeit. Angew. Phys.*, vol. 2, pp. 152–160; April, 1950.) Graphs are given of the paths of the ordinary and extraordinary rays for a signal of wavelength 80 m both for vertical and oblique incidence on a linearly ionized and on a parabolically ionized layer at a height of 200–300 km. At vertical incidence the ordinary ray is deflected northwards, the extraordinary ray southwards. For small angles of incidence, ray paths are pointed at their apex and the height of reflection is constant. The ray theory may give inaccurate results near the point of reflection. See also 718 of April.

621.396.11+621.396.81].029.64 2876
Progression of Microwave Radio Scintillations [fluctuations] at Wind Speed on an Overwater Path—A. W. Straiton and H. W. Smith. (Proc. I.R.E., vol. 38, pp. 825–826; July, 1950.) 3.2-cm radio signals transmitted over a 26.5-mile overwater path were recorded by two receivers (*a*) with a horizontal separation of 65 ft. normal to the radio path, (*b*) with a vertical separation of 10 ft. Signal fluctuations progressed at about wind speed between the horizontally separated receivers; a downward but less definite progression was observed for the case of vertical separation. See also 3241 of 1949 and 1483 of July (Straiton et al.).

621.396.81 2877
Propagation of 10-Mc/s Waves over Ranges of 500–1300 km—R. G. Sacasa. (*Rev. Telecomun.* (Madrid), vol. 5, pp. 2–8; December, 1949.) Data for 10 Mc as optimum working frequency are taken from the diagram previously discussed (2614 above); these are rearranged in tabular form and considered in detail. Experimental results for reception during November 1949 of Swiss transmissions on 11.865 and 9.665 Mc are presented.

621.396.81 2878
Propagation of 12-Mc/s and 15-Mc/s Waves over Ranges of 500–2400 km—R. G. Sacasa. (*Rev. Telecomun.* (Madrid), vol. 5, pp. 3–14; March, 1950.) Tabulation and discussion of data obtained from the diagram previously given (2614 of December). Experimental results for 15.17-Mc transmissions from Oslo during the period October 1949–February 1950 are presented. Agreement with prediction is very satisfactory.

621.396.812.029.64 2879
Microwave Attenuation Statistics Estimated from Rainfall and Water Vapor Statistics—H. E. Bussey. (Proc. I.R.E., vol. 38, pp. 781–785; July, 1950.) Curves are derived giving predictions of the number of hours per year during which the overall attenuation of a 50-km path and a 1-km path at Washington will exceed various values, for frequencies above 1 kMc. The results are obtained by analyzing available meteorological data, theoretically derived factors (515 of 1947) being used for converting into radio attenuation values. Extension of the method to other parts of the U.S.A. is discussed.

RECEPTION

621.396.621:621.396.619.13 2880
Detector Circuits for Frequency-Modulation Receivers—C. J. Boers. (*Fernmeldetech. Z.*, vol. 3, pp. 296–300; August, 1950.) The disturbing effects of undesired am are examined, and the action of limiters is explained. A subsequent paper is to deal with particular types of discriminator circuit.

621.396.621:621.396.619.13:621.396.931 2881
Mobile F.M. Broadcast Reception—R. C. Barritt. (*Electronics*, vol. 23, pp. 74–78; August, 1950.) A report of results obtained with various types of antenna and circuit for fm broadcast reception in moving vehicles. Increased sensitivity and improved limiting circuits appear to be necessary.

621.396.621:621.396.822 2882
Analysis of the Signal/Noise Ratio in U.H.F. Receivers—E. W. Herold. (*Rev. Telecomun.* (Madrid), vol. 5, pp. 47–60; March, 1950.) A translation from "Radio at Ultra-High Frequencies," vol. 2, published by RCA Review. See 2336 of 1942.

621.396.622.015.7†:621.396.822 2883
Detection of a Pulse Superimposed on Fluctuation Noise—B. M. Dwork. (PROC. I.R.E., vol. 38, pp. 771–774; July, 1950.) The frequency response of a linear device giving the maximum value for the ratio between peak amplitude of the signal and the rms value of the noise at the output is determined analytically for a known pulse superimposed on fluctuation noise with a known spectrum. The result is applied to the case in which the fluctuation noise has a uniform frequency distribution; the optimum network is then physically realizable if the pulse differs from zero for only a finite interval of time. The noise-suppression efficiency of a conventional RC circuit is computed for rectangular and for exponentially decaying pulses.

621.396.662:[621.396.619.13+621.397.62 2884
A New TV-FM Tuner—C. W. Lytle. (*Tele-Tech*, vol. 9, pp. 21–23, 86; June, 1950.) Detailed description of a continuously variable inductive tuner in which tuning is effected by a rotor carrying copper vanes serving as short-circuited turns when brought near the inductor coils. Two sets of coils and vanes are used, one set for the high and the other for the low US television band.

621.396.662.085.3 2885
Hypersensitive Resonance Indicator—R. L. Ives. (*Electronics*, vol. 23, pp. 118–154; August, 1950.) Application of Foster-Seeley and Doppelganger discriminators to resonance indication for weak and fading signals is discussed. Circuit details are given of a complete unit that can be added to any standard superheterodyne receiver.

621.396.81 2886
Propagation of 10-Mc/s Waves over Ranges of 500-1300 km—Sacasa. (*See* 2877.)

621.396.81 2887
Propagation of 12-Mc/s and 15-Mc/s Waves over Ranges of 500-2400 km—Sacasa. (*See* 2878.)

STATIONS AND COMMUNICATION SYSTEMS

621.39.001.11 2888
Statistical Theory of Communication—J. B. Wiesner. (*Proc. NEC* (Chicago), vol. 5, pp. 334–341; 1949.) Difficulties in the analysis of communication systems are pointed out and the statistical methods developed by Wiener and Shannon are outlined. The use of statistical concepts to provide a new kind of filtering in the time domain is described. See also 2465 above (Wiener) and 1649 of 1949 (Shannon).

621.394/.395].44 2889
Carrier-Frequency Technique in Germany, 1935–1945—G. Hässler. (*Elektrotechnik*, Berlin, vol. 2, pp. 161–168; June, 1948.)

621.395:621.318.572 2890
Voice-Switched Intercom—R. H. Baer. (*Electronics*, vol. 23, pp. 79–81; August, 1950.) Instead of a talk-listen switch this system uses a 4-terminal repeater with a flip-flop circuit that unblocks gated amplifiers alternately 30 times per sec. Incoming speech signals stop the flip-flop and keep open the desired channel without clipping syllables.

621.395.44 2891
A Twelve-Channel Carrier Telephone System for Use on Cables—T. B. D. Terroni. (*Strowger Jour.*, vol. 7, pp. 62–81; July, 1950.) The principal factors which determine the design of 12-channel systems are outlined and the single-modulation method using crystal filters and the group-modulation method using inductor-capacitor filters are discussed. The special features of a group-modulation system are described and performance details are given.

621.396.1:519.242 2892
An Extension of Wiener's Theory of Prediction—Zadeh and Ragazzini. (*See* 2808.)

621.396.3+621.396.5](43) 2893
Survey of the [German] Overseas Radio Service—W. Kronjäger. (*Fernmeldetech. Z.*, vol. 3, pp. 265–271; August, 1950.) The different telephony and telegraphy systems are indicated and the organization of the corresponding services is described. Traffic figures are given for 1949.

621.396.61/.62(621.396.931 2894
Mobile Radio Unit—D. Samuelson. (*FM-TV*, vol. 10, pp. 18–19, 33; July, 1950.) Design details, with illustrations, of a small transmitter-receiver capable of operating in a single channel without picking up adjacent-channel signals or causing interference with other systems. Transmitter power output is 12 w on 25–50 Mc and 10 w on 151–174 Mc.

621.396.65:621.396.619.11/.13 2895
Modulation Conversion in a Wave Guide—P. S. Rogell. (*Jour. Appl. Phys.*, vol. 21, pp. 629–631; July, 1950.) Theory and design equations are presented for the conversion of a narrow-band FM microwave signal into an almost pure AM signal within a waveguide of given dimensions. Frequency relations and guide dimensions are arranged so that the FM sidebands are shifted with respect to the carrier until they become AM sidebands at the guide output. A complex intelligence signal may be transmitted with negligible distortion if it is used for AM of an intermediate carrier which is then applied for FM of the microwave carrier.

621.396.65.029.63/.64:621.397.5 2896
2000- and 7000-Mc/s TV Microwave Relays—E. D. Hilburn. (*TV Eng.*, vol. 1, pp. 8–11; 18–21; 16, 35; 26; March-June, 1950.) Relay equipment for transmission of outside programs to station WMAL-TV is described. The 7-kMc equipment is portable and serves for local transmissions over line-of-sight paths up to about 20 miles, while the more powerful 2-kMc equipment is used between fixed stations and is effective at much greater ranges. Installation and operation procedures are discussed.

621.396.7+621.397.7](73)(058.7) 2897
Tele-Tech TV-FM-AM Station & Studio Equipment Directory, 1951—(*Tele-Tech*, vol. 9, pp. 37–39, 84; June, 1950.) A very comprehensive list of U. S. stations of all types, and of manufacturers of equipment directly or indirectly connected with radio and television.

621.396.712.029.6:621.396.619.13(43) 2898
The Technique of U.S.W. Broadcasting—L. Rohde. (*Fernmeldetech. Z.*, vol. 3, pp. 286–292; August, 1950.) Germany is the first European country to introduce ultra-short wave FM broadcasting. American practice has been studied and full advantage is taken of the possibilities of FM, viz., high quality, economic use of frequency channels and reduced interference. Radio links are preferred to cable for all but very short distances. Tetrodes are used for power up to 1 kw, triodes for higher power. The advantages of small automatically controlled transmitters are pointed out, and filter arrangements are described which permit two programs to be radiated from the same antenna.

621.396.712(43) 2899
Basis of U.S.W. Plan for the U. S. Zone [of Germany]—F. Gutzmann. (*Fernmeldetech. Z.*, vol. 3, pp. 276–278; August, 1950.)

621.396.712(43) 2900
The U.S.W. Network of the North-West Germany Broadcasting System—W. Nestel. (*Fernmeldetech. Z.*, vol. 3, pp. 282–285; August, 1950.)

621.396.712(43) 2901
The U.S.W. Network of the South-West [Germany] Broadcasting System—Knöpfel. (*Fernmeldetech. Z.*, vol. 3, pp. 279–281; August, 1950.)

SUBSIDIARY APPARATUS

621.526 2902
A Note on the Error Coefficients of a Servo Mechanism—J. L. Bower. (*Jour. Appl. Phys.*, vol. 21, p. 723; July, 1950.)

621.316.722.1:621.316.261 2903
A Preservation Rectifier with Electronically Stabilized Charging Voltage—E. Cassee. (*Philips Tech. Rev.*, vol. 11, pp. 253 259; March, 1950.) The difference between the charging voltage of an accumulator battery and a constant reference voltage is amplified and used to control the dc bias of a transductor in series with the secondary of the transformer feeding the rectifier in the charging equipment The charging voltage is thereby maintained constant to within 0.5 per cent for mains frequency deviations of 4 per cent or voltage variations of 10 per cent.

621.355.2+621.355.8 2904
Military Storage Batteries—H. Mandel. (*Elec. Eng.*, vol. 69, pp. 619–621; July, 1950.) Recent developments are described, particularly as regards lead-acid batteries and alkaline batteries with sintered Ni-Cd plates, and obtaining satisfactory performance at very low temperatures.

TELEVISION AND PHOTOTELEGRAPHY

621.397.5:621.317.799† 2905
Inexpensive Picture Generator—Popkin-Clurman. (*See* 2842.)

621.397.5:621.396.65 2906
Televising the Boat Race—1950: The Engineering Problems—T. H. Bridgewater, R. H. Hammans, and S. N. Watson. (*BBC Quart.*, vol. 5, pp. 107–115; Summer, 1950.) A detailed account of the system of radio and cable links connecting the equipment on the launch following the race with the Alexandra Palace transmitter.

621.397.5:621.396.65.029.63/.64 2907
2000- and 7000-Mc/s TV Microwave Relays—Hilburn. (*See* 2896.)

621.397.5(43) 2908
The Development of Television by the German Post Office—H. Pressler. (*Fernmeldetech. Z.*, vol. 3, pp. 302–308; August, 1950.) A historical review, with extensive bibliography.

621.397.5(43) 2909
Development of Television Technique by the Fernseh G.m.b.H. 1939–1945—H. Bähring, W. Dillenburger, R. v. Felgel-Farnholz, T. Mulert, F. Rudert, and H. Strübig. (*Fernmeldetech. Z.*, vol. 3, pp. 308–316; August,

1950.) A review of the most important advances made during the period when normal publication was suspended.

621.397.6 2910
A Film Dubbing and Review Suite for Television Film Production—N. F. Chapman. (*BBC Quart.*, vol. 5, pp. 116–128; Summer, 1950.) Detailed account of facilities noted in 1539 of July.

621.397.61:621.396.619.2 2911
An Analysis of Single and Double Sideband Transmission—G. E. Hamilton and R. G. Artman. (*TV Eng.*, vol. 1, pp. 22–24; July, 1950.) A mathematical analysis of double sideband and single-sideband transmission. The attenuation may vary between 6 db and 7 db according to the modulation factor. In double-sideband operation the detector need respond only to the modulating frequencies, but for single-sideband transmission a detector with infinite bandwidth is needed to give faithful reproduction.

621.397.61:621.396.645.018.424:621.3.088.7 2912
The Compensation for Phase Errors in Wide-Band Video Amplifiers—Brain. (*See* 2752.)

621.397.61:621.396.673 2913
1 057-Foot FM-TV Antenna—(*See* 2722.)

621.397.611.2 2914
A New Image Orthicon—R. B. Janes, R. E. Johnson, and R. R. Handel. (*Proc. NEC* (Chicago), vol. 5, pp. 140–147; 1949.) The spectral sensitivity characteristics of image orthicons are discussed and the properties of a new panchromatic high-sensitivity photosurface used in the RCA Type 5820 orthicon are described. This makes television possible under poor lighting conditions. Production problems for the Type 5820 orthicon are briefly discussed. See also 2361 of October.

621.397.621.2:621.385.832 2915
The Design and Fabrication of TV Picture Tubes—Hoagland. (*See* 1943.)

621.397.62:621.314.2 2916
A Universal-Application Cathode-Ray Sweep Transformer with Ceramic Iron Core—C. E. Torsch. (*Proc. NEC* (Chicago), vol. 5, pp. 130–139; 1949.) The high-μ high-Q ceramic-iron cores now available enable cathode-ray tube sweep transformers of high efficiency to be produced. The design of a unit which can be used with any direct-view picture tube is described and typical circuits for use with the unit are given.

621.397.62+621.396.619.13]:621.396.662 2917
A New TV-FM Tuner—Lytle. (*See* 2884.)

621.397.62:621.396.662 2918
Two New Television Tuners—M. F. Melvin. (*Proc. NEC* (Chicago), vol. 5, pp. 148–160; 1949.) Description and performance details of 3-section and 4-section "spiral" inductuners which are both cheaper and mechanically simpler than previous solenoid designs.

621.397.62:621.396.67 2919
An Automatic Built-In Antenna for Television Receivers—K. Schlesinger. (*Proc. NEC* (Chicago), vol. 5, pp. 292–302; 1949.) See 819 of May.

621.397.82 2920
Interference Patterns in Television Pictures—(*Jour. Telev. Soc.*, vol. 6, pp. 22–23; January-March, 1950.) Photographs taken by the GPO officials are shown, illustrating the disturbing effects produced on television pictures by different types of interference.

621.397.5 2921
Television Simplified [Book Review]—M. S. Kiver. Publishers: D. Van Nostrand Co., New York, 3rd edn 1950, 556 pp., \$6.50. (Proc. I.R.E., vol. 38, p. 832; July, 1950.) The basic principles of television are explained for the nonmathematical reader. The book deals almost entirely with receivers, and includes a chapter on servicing and installation. New chapters cover intercarrier television sound and color television.

TRANSMISSION

621.396.61 2922
Lorenz 10-kW U.S.W. Transmitter for F.M. Broadcasting—G. Brauer. (*Fernmeldetech. Z.*, vol. 3, pp. 292–296; August, 1950.) Two of these transmitters have been in operation in Germany since early 1950. An explanation is given of the differences of design called for at frequencies of 87.5–100 Mc as compared with transmitters for lower frequencies. The grounded-grid triode power-amplifier tube is described in some detail.

621.396.61:621.396.619.13 2923
3000 Watts for State Police—W. Fingerle, Jr. (*FM-TV*, vol. 10, pp. 11–12, 33; July, 1950.) Illustrated description of a FM transmitter operating in the range 40–50 Mc. Tests indicate that such transmitters give effective state coverage.

621.396.611.21.029.63:621.396.931 2924
Crystal Control for Citizens Band—I. Gottlieb and I. R. Mednick. (*Electronics*, vol. 23, pp. 96–98; August, 1950.) Stabilized operation of a war-surplus BC-645 unit on 460 Mc is effected by the addition of a 2-tube exciter unit and by use of the Type 316-A tube in the BC-645 as a frequency doubler. Frequencies in the band 460–470 Mc are derived from crystals with fundamental frequencies between 8.52 Mc and 8.70 Mc. See also 517 of 1949 (Samuelson).

621.396.619.13 2925
A Versatile Crystal Controlled Source of Angle Modulation—J. F. Gordon. (*Proc. NEC* (Chicago), vol. 5, pp. 512–518; 1949.) A device is described which produces large deviations and increased modulation sensitivity without loss of transmitter stability; the relatively small number of tubes used results in a simple circuit. An experimental unit and details of its performance are also described.

TUBES AND THERMIONICS

621.314.632 2926
G.E.C. Germanium Crystal Rectifiers—(*Instr. Practice*, vol. 4, pp. 427–428; June, 1950.) Characteristics of four available types are tabulated. All are sealed in glass envelopes and have the metal point cemented to the Ge crystal.

621.314.671 2927
A New Rectifier Tube for Extremely High Power and Voltage Levels—T. H. Rogers. (*Proc. NEC* (Chicago), vol. 5, pp. 482–492; 1949.) The factors which control the design of high-vacuum rectifiers and limit their use for high-current applications are discussed, and new design principles are outlined which have been evolved to raise these limits sufficiently to meet the requirements of devices using high-current high-voltage supplies. New tubes described can handle a peak current of 10 a and an inverse voltage of 110 kv.

621.383 2928
Design Features and Some Applications of a New Photocell—J. H. Crow and V. C. Rideout. (*Proc. NEC* (Chicago), vol. 5, pp. 506–511; 1949.) See 1288 of June.

621.383.27† 2929
Photocells with Secondary-Electron Multipliers—N. Schaetti. (*Helv. Phys. Acta*, vol. 23, pp. 108–120; February, 3, 1950. In German.) The production and properties of various photocathodes and secondary-emission layers is discussed. An 18-stage multiplier with an Ab-Cs photocathode and Ag-Mg coating for the multiplier plates has a sensitivity of 40–60 μa/lumen and a total amplification of $10^{10}-10^{12}$ with a stage voltage of 200 v.

621.383.4 2930
The Phototransistor—J. N. Shive. (*Bell Lab. Rec.*, vol. 28, pp. 337–342; August, 1950.) The essential element in the device is a wafer of Ge with a spherical dimple ground in one face so that at the centre, where a phosphor-bronze wire 0.005 in. diameter makes contact, the thickness is about 0.003 in. Operation of the cell depends on the decrease in resistance of the Ge element between its containing ring and the collector wire on exposure to light. For a particular cell operated in series with a 20-k Ω resistor, the calculated current output was about 0.07 ma per millilumen. With fluctuating light the response curve is substantially flat up to 200 kc, the highest frequency so far used. The sensitivity is greatest in the spectral region 1.0–1.5 μ. An outline of the theory of the mechanism of photoconductivity is given.

621.385:621.396.621 2931
The 6BN6 Gated Beam Tube—R. Adler. (*Proc. NEC* (Chicago), vol. 5, pp. 408–416; 1949.) See 1292 of June.

621.385:621.396.621 2932
The 6BN6 Gated Beam Tube—A. P. Haase. (*Proc. NEC* (Chicago), vol. 5, pp. 417–426; 1949.) See 1292 of June (Adler).

621.385–712 2933
New Type of Radiator for High-Power Transmitting Tubes—O. Schärli. (*Brown Boveri Rev.*, vol. 36, pp. 311–315; September, 1949.) A radiator system is described which uses transverse fins consisting of sheet-metal rings separated by spacers and riveted together. Applied to the Type-ATL 35–1 tube it can handle an anode dissipation of 46 kw.

621.385.032.216 2934
Conduction Processes in the Oxide-Coated Cathode—R. Loosjes and H. J. Vink. (*Philips Tech. Rev.*, vol. 11, pp. 271–278; March, 1950.) Preparation and activation of oxide-coated cathodes is described. Electrons emitted by the coating are replaced by conduction from the metal core and it is suggested that this conduction is due to two processes acting together, electronic conduction of the grains at temperatures $<800°$K and conduction through the electron gas in the pores between the grains at higher temperatures. The lagging of conduction behind emission at temperatures $>1,000°$K is explained by the effect of the space charge upon the electron density and upon the field in the pores.

621.385.032.24:537.58 2935
Experiments on Grid Emission—A. A. Rusterholz. (*Brown Boveri Rev.*, vol. 36, pp. 300–304; September, 1949.) Methods are discussed which result in reduced primary grid emission, particularly in transmitting tubes with thoriated-tungsten cathodes. Carburization of the Ta grid wires at a high temperature in CO or CO_2 has been suggested as a means of preventing an increase of grid emission due to activation by Th evaporated from the filament. Experiments with grids carburized in an atmosphere of H_2 saturated with benzene vapor showed, however, that no improvement was effected. Investigations of carburization in CO or CO_2 are being continued.

621.385.032.442:621.3.025.4 2936
Hum Characteristics of A.C.-Heated Transmitting Tubes—E. Atti. (*Brown Boveri Rev.*, vol. 36, pp. 305–311; September, 1949.) The hum level in transmitting tubes with directly heated tungsten filaments can be reduced very considerably by use of specially designed cathode systems and 3-phase or 6-phase heater supplies. Careful balancing of the phases and accurate alignment of the grid and the filament wires is essential. In the new 200-kw broadcasting transmitter at Beromünster, the hum level in the alternating-frequency output stage, which consists of two class-B triodes with 3-phase heating, is −57db without feedback, which lowers it further to −61db.

621.385.2 2937
The High-Frequency Response of Cylindrical Diodes—E. H. Gamble. (*Proc. NEC* (Chicago), vol. 5, pp. 387–402; 1949.) The problem is considered as a quasistationary one and equations are derived for an ideal diode in which the electron paths are normal to the emitting surface. The relations thus obtained are applied to space-charge-limited and temperature-limited operation. Numerical solutions of the nonlinear integral equations were obtained from analogue-computer solutions for the corresponding differential equations. The results indicate the essential correctness of the treatment of the problem.

621.385.3:621.315.592†]:621.396.822 2938
Low-Frequency Noise in Transistors—H. T. Mooers. (*Proc. NEC* (Chicago), vol. 5, pp. 17–22; 1949.) The alternating-frequency spectra of both emitter and collector noise in six type-A transistors were investigated. Noise output varies with frequency, but not inversely. Emitter noise does not contribute significantly to the noise output, and this output is independent of dc voltage, current and resistance. Good correlation is found between noise power and forward transfer impedance. The noise output may be predicted fairly accurately at any given operating point, for any bandwidth up to 15 kc. The lowest input signal strength required to produce a given output signal-noise ratio can also be estimated.

621.385.4:621.319.43 2939
Variable-Capacitance Tube for Frequency Control—R. W. Slinkman. (*Sylvania Technologist*, vol. 3, pp. 18–20; July, 1950.) Frequency stabilization of very-high-frequency and ultra-high-frequency oscillators in FM receivers is effected by means of a tetrode with a bimetallic anode. The curvature of the anode varies with changes of frequency and affects the value of a capacitor within the tube which forms part of the oscillator tank circuit. External series capacitors enable the effective control bandwidth to be adjusted. Tests in a commercial FM receiver and in an experimental 600-Mc television converter have given promising results.

621.385.832 2940
Beam Deflection Nonlinear Element—A. A. Soltes. (*Electronics*, vol. 23, pp. 122–178; August, 1950.) A parabolic mask placed between deflector plates and collector enabled a square-law static characteristic to be obtained with an electron beam of rectangular cross-section. Instantaneous squaring of radar-type signals to an accuracy of 2 per cent of full-scale, at an input frequency to the deflector plates of 40 Mc, was achieved by this means in the Raytheon tube Type QK-256.

621.385.832 2941
Dimensional Tolerances in Cathode-Ray-Tube Guns—H. Moss, L. Woodbridge, and M. Webb. (*Proc. IEE* (London), Part III, vol. 97, pp. 277–283; July, 1950.) Preliminary experiments show that cathode tilt in the triode has negligible effect on beam centrality and symmetry. Effects of lateral displacement and tilt of the first anode for various grid-anode spacings are determined experimentally for several types of triode geometry. The astigmatism due to the tilt, displacement and deformation of the final lens elements is also investigated experimentally and an effective type of ion-trap electron gun is described.

621.385.832:621.3.087 2942
The Recording Storage Tube—R. C. Hergenrother and B. C. Gardner. (PROC. I.R.E., vol. 38, pp. 740–747; July, 1950.) A cathode-ray tube has a mesh screen coated on the face away from the electron gun with a charge-retaining layer. The potential of an output-signal screen located further along the tube is made negative relative to the cathode, so that when the signal is applied "written" the beam passes through the mesh screen and is reflected to strike its rear (storage) surface, whereas when the signal is taken off "read" the beam strikes the output-signal screen, which in this case is made more positive than the storage-screen mesh potential, and does not disturb the stored charges. The signal can thus be read 20,000 times without appreciable deterioration and with a decrease in signal level of only a few per cent.

621.385.832:621.397.611.2 2943
The Design and Fabrication of TV Picture Tubes—K. A. Hoagland. (*TV Eng.*, vol. 1, pp. 16–21, 35 and 16–17; March and April, 1950.) A survey of American manufacturing processes and discussion of present trends in cathode-ray tube design, with particular attention to beam focusing the use of slant-field and bent-gun ion traps, metal-cone construction etc.

621.396.615.14:621.385.029.63/.64 2944
The Helix as Resonator for Generating Ultra High Frequencies—B. B. van Iperen. (*Philips Tech. Rev.*, vol. 11, pp. 221–231; February, 1950.) The action of the travelling-wave tube as an amplifier is described briefly and its use as an ultra-high-frequency generator is discussed. The resonances of the helix play an important part in this latter case. A relatively simple method is developed for determining under what conditions oscillations are possible and at what current intensity they begin. Results are given of some experiments which confirm the accuracy of the theory. An experimental tube with gas-concentrated beam is described.

621.396.615.141.2 2945
The Turbator—F. Lüdi. (*Brown Boveri Rev.*, vol. 36, pp. 315–318; September, 1949.) The evolution is reviewed of the Brown Boveri type of magnetron, which comprises a Ba-Sr oxide cathode and a single annular cavity resonator capacitively coupled to the anode segments. The Mo sheet-metal construction of the anode enables an anode dissipation of 200 w to be attained. A glass-enclosed 15-w type is being developed.

621.396.615.141.2:621.317.361 2946
Measurement of the Space-Charge Resonance Frequencies in a Multicavity Magnetron—P. Fechner. (*Compt. Rend. Acad. Sci.* (Paris), vol. 231, pp. 270–271; July 24, 1950.) The magnetron is coupled to a waveguide which is terminated by its characteristic impedance and energized by a klystron generator. Resonance conditions are determined from measurements of the transmission coefficient in the waveguide for different values of magnetic field and anode voltage. The results obtained verify the theory previously given (2678 of December). See also 2680 of December.

621.396.615.142 2947
Radial-Beams Velocity-Modulated Microwave Tube.—C. G. Lob and D. F. Holshouser. (*Proc. NEC* (Chicago), vol. 5, pp. 403–407; 1949.) The tube consists of a coaxial resonator of length $\lambda/2$, cut in the middle perpendicular to its axis of symmetry so as to constitute two coaxial cavities, each operating in the $\lambda/4$ mode. Surrounding the cut in the resonator is a gun structure with a ring cathode and two focusing electrodes. The action of the tube is similar to that of a two-gap klystron or of a reflex klystron, depending on the operating conditions. Test results on three experimental tubes are given. An output of about 3 mw was obtained at a wavelength of 4 cm.

621.396.615.142.2 2948
Efficiency of Reflex Oscillators—W. G. Sheperd. (*Proc. NEC* (Chicago), vol. 5, pp. 500–505; 1949.) Analysis of the efficiency and electronic tuning of a reflex oscillator as affected by the use of different modulation coefficients for the outgoing and return transits of the interaction gap.

621.396.645:621.396.822 2949
Noise Suppression in Triode Amplifiers—van der Ziel (*See* 2751.)

MISCELLANEOUS

621.396.7+621.397.7](73)(058.7)
621.396.6.65(73)(058.7) 2950
Tele-Tech TV-FM-AM Station & Studio Equipment Directory, 1951—(*See* 2897.)

658.562:519.283 2951
The Theory of Sampling Inspection Plans—H. C. Hamaker. (*Philips Tech. Rev.*, vol. 11, pp. 260–270; March, 1950.) Mathematical principles underlying sampling inspection are discussed. Two parameters for describing an operating characteristic, termed "point of control" and "relative slope," are introduced and their relation to sample size and acceptance number is established. Various other parameters in use are reviewed and reasons are given for the choice of the point of control and sample size as a practical set.

621.3 2952
Basic Electrical Engineering [Book Review]—G. F. Corcoran. Publishers: Chapman & Hall, London, 1949, 449 pp. 27s. (*Beama Jour.*, June, 1950. vol. 57, p. 179.) ". . . the treatment . . . is clear, smoothly sequential, succinct but without undue condensation . . . It is a most commendable piece of work."

621.396 2953
Radio Handbook [Book Review]—R. L. Dawley, (Ed.). Publishers: Editors and Engineers, Santa Barbara, California, 12th edn. 1949, 320 pp., $3.25. (*Electronics*, vol. 23, pp. 142, 144; August, 1950.) An all-construction edition dealing with transmitter and receiver equipment, including mobile sets. "This edition does not supersede the 11th edition [2680 of 1948], which contains different information and remains current."

621.396/.397 2954
Outline of Radio, Television and Radar [Book Review]—R. S. Eleven, T. J. Fielding, E. Molloy, H. E. Penrose, C. A. Quarrington, M. G. Say, R. C. Walker, and G. Windred. Publishers: Chemical Publ. Co., Brooklyn, 1950, 688 pp., $12.00. (*Electronics*, vol. 23, p. 142; August, 1950.) A book compiled by eight British engineers. "Extensive use of British terminology throughout, along with descriptions and illustrations of British products . . . does not impair the usefulness of the book to those seeking to keep in touch with British practice."

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942	Vol. 30	January to May, October to December, inc.			
943	Vol. 31	February to December, inc.	1948	Vol. 36	All 12 issues
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45 IRE 14 S1 Standards on Piezoelectric Crystals: Recommended Terminology, 1945. (iv+4 pages, 8½×11 inches)	$0.20
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48 IRE 22 S1 Standards on Television: Methods of Testing Television Receivers, 1948. (Adopted by ASA C16.13-1949). (vi+32 pages, 8½×11 inches)	$1.00
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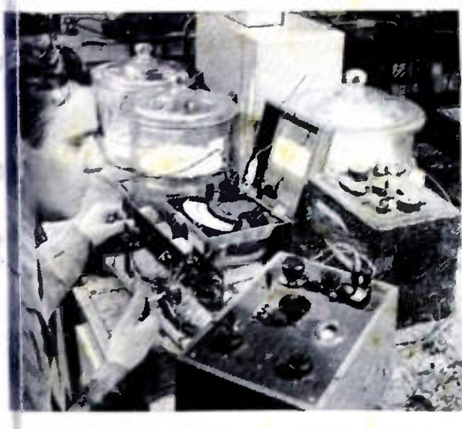

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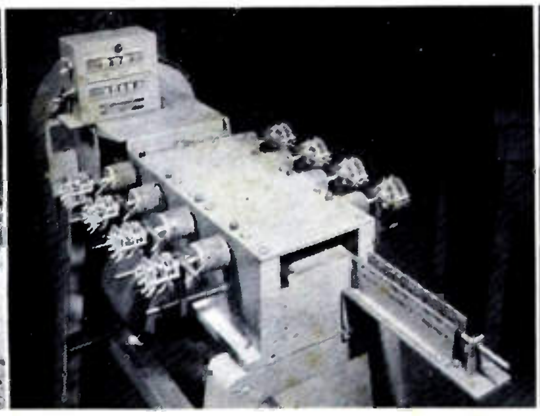

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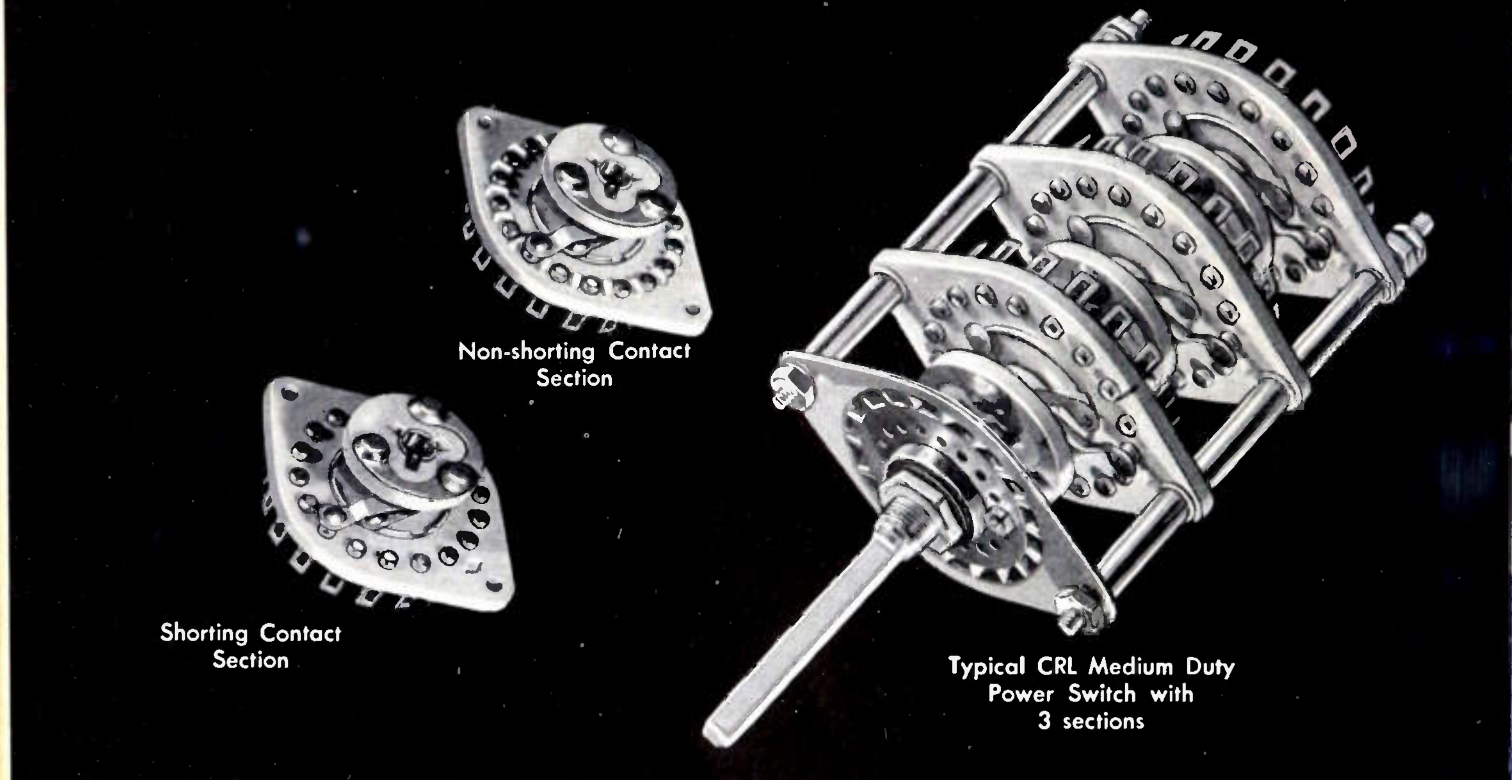

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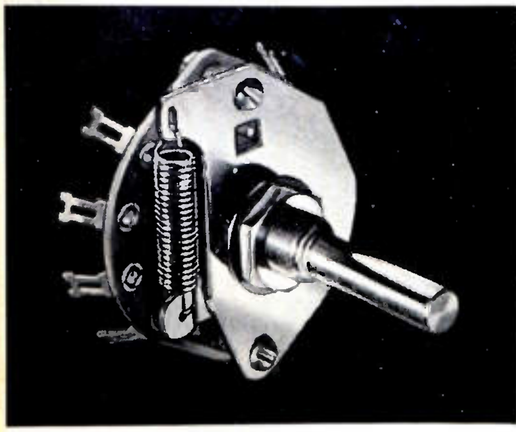

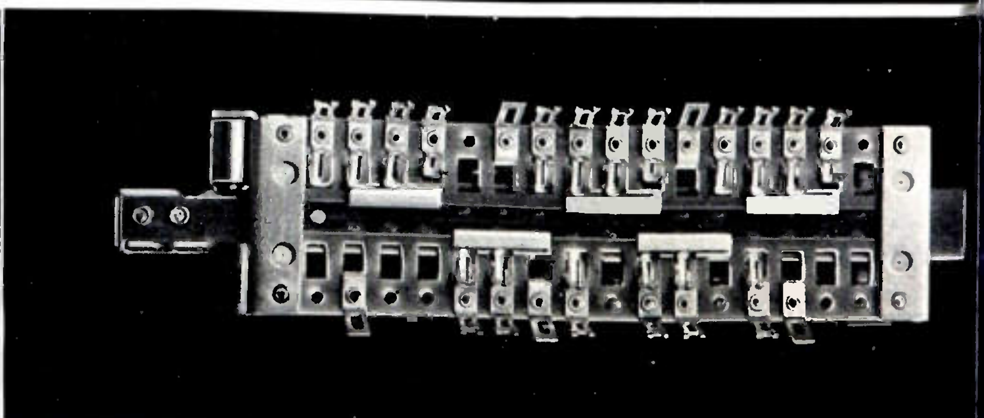

2 Great step forward in switching is CRL's New Rotary, Coil, Spring and Cam Index Switch. It gives you smoother action, longer life.

3 Centralab's development of a revolutionary, new *Slide Switch* vastly facilitates AM and FM set design! Flat, horizontal design saves valuable space, allows short leads, convenient location to coils, reduced lead inductances for increased efficiency in low and high frequencies. CRL Slide Switches are rugged and dependable.

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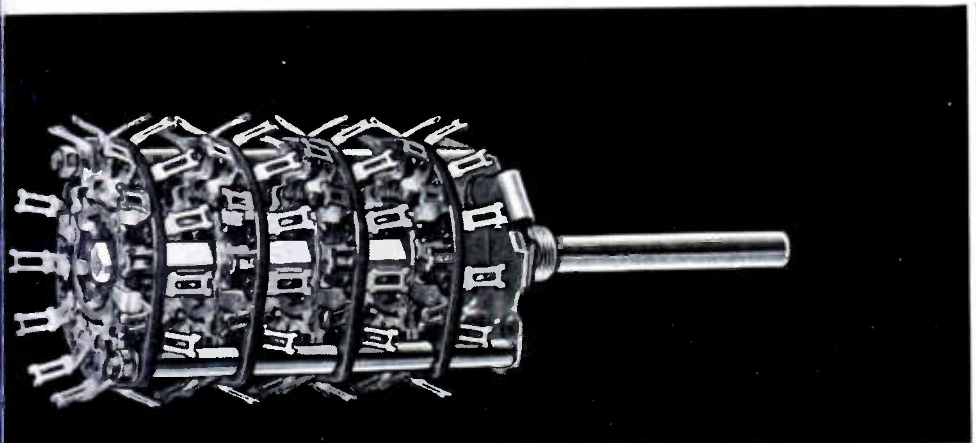
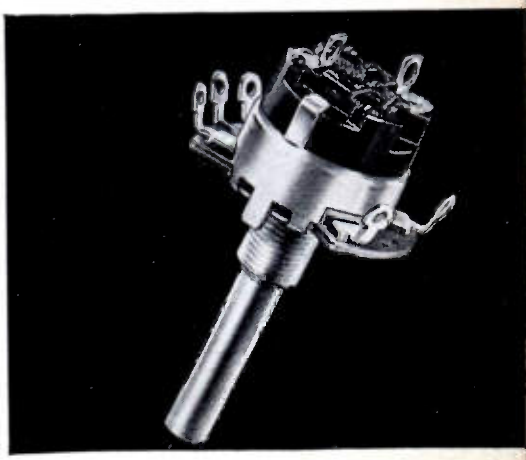
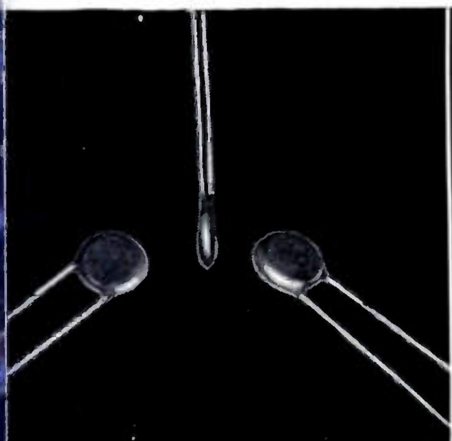
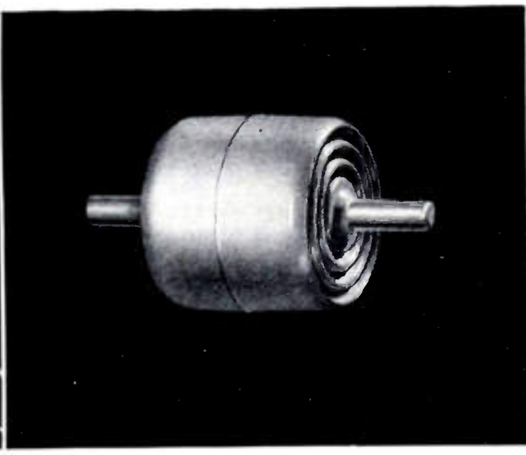


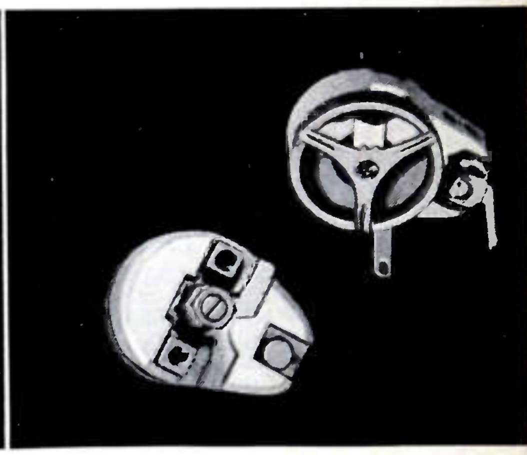


4 24 insulated clips per section assure variety of switching combinations. This double-wipe style switch can be CRL built to your specifications. Successfully used in TV up to 200 megacycles. Ratings: 1 amp at 6 v. Stator and rotor highest grade laminated phenolic. Clips silver-plated or silver alloy.

5 CRL's new high quality Model 2 Radiohm Controls specifically designed for TV, radio, other electronic equipment. Lower noise level, longer life.



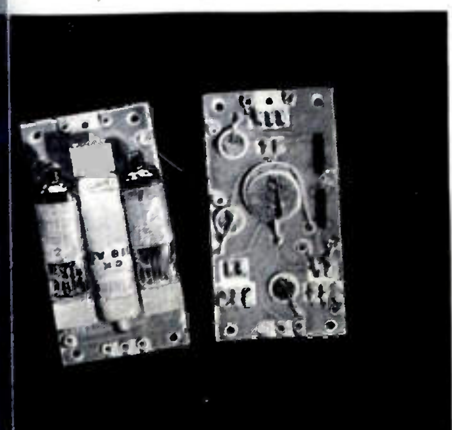


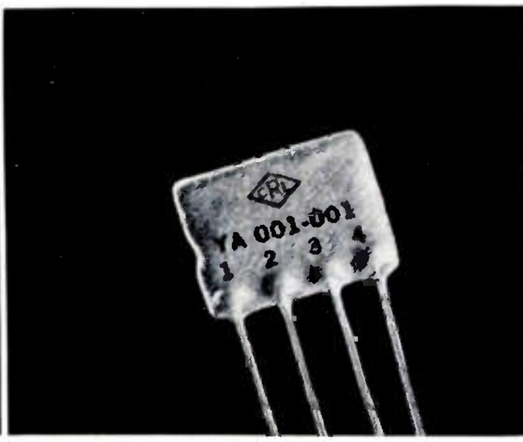


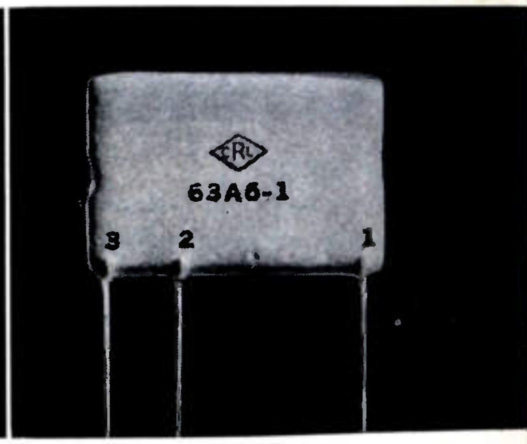
6 For by-pass or coupling applications, check Centralab's original line of ceramic disc Hi-Kaps. Disc Hi-Kaps are smaller than a dime.

7 Hi-Vo-Kaps (10-20-30 kv) are filter and by-pass capacitors combining high voltage, small size and variety of terminal connections to fit most TV needs.

8 Ceramic Trimmers are made in five basic types. Full capacity change within 180° rotation. Spring pressure maintains constant rotor balance.







9 Centralab's *Ampec*, above, is an integral assembly of tube sockets, capacitors, resistors and wiring combined into one miniature amplifier unit.

10 Couplate consists of plate and grid resistors, plate by-pass and coupling capacitors. Minimum soldered connections speed production.

11 This is the new CRL Vertical Integrator Network used in TV sets. Variations of this Centralab integrator plate are available on special order.

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- **42-3** — BC TUBULAR HI-KAPS — capacitors for use where temperature compensation is unimportant.
- **42-4R** — BC DISC HI-KAPS—miniature ceramic BC capacitors.
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- **981** — HI-VO-KAPS — capacitors for TV application. For jobbers.
- **42-18** — TC CAPACITORS — temperature compensating capacitors.
- **42-102** — CAPACITORS — high-voltage capacitors.
- **975** — FT HI-KAPS — feed-thru capacitors.

Centralab Switches

- **953** — SLIDE SWITCH — applies to AM and FM switching circuits.
- **970** — LEVER SWITCH — shows indexing combinations.
- **995** — ROTARY SWITCH — schematic application diagrams.
- **722** — SWITCH CATALOG — facts on CRL'S complete line of switches.

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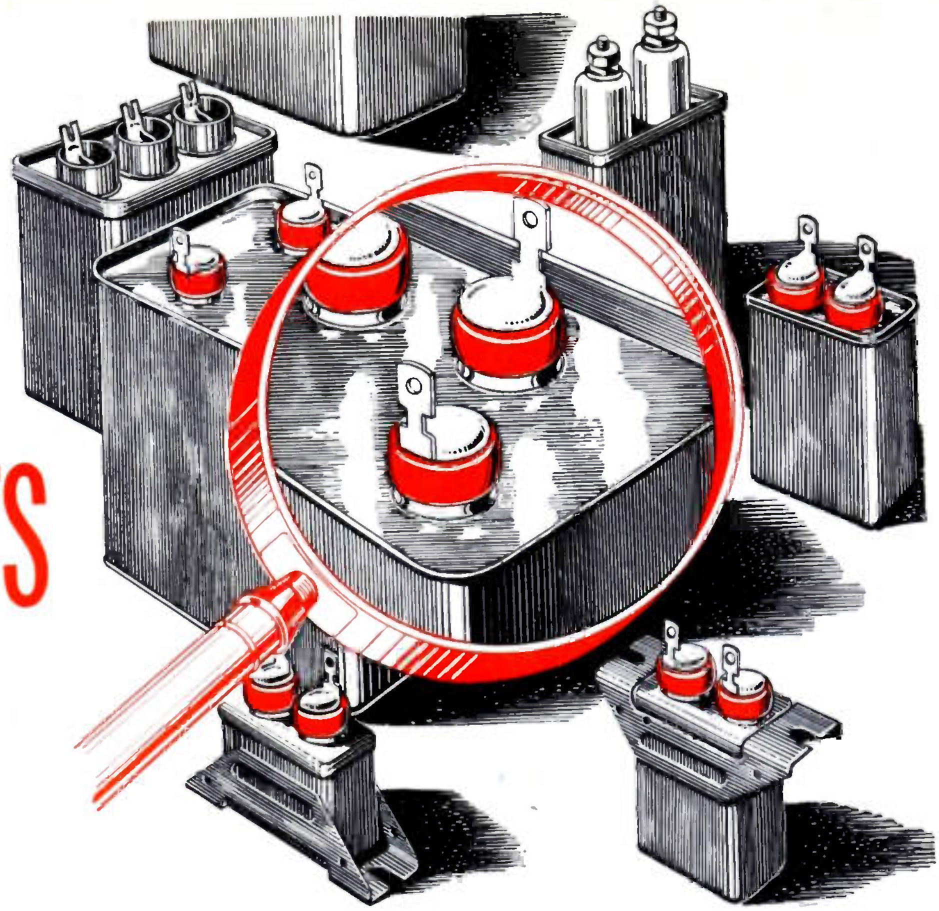

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SECTION MEETINGS

Akron

"X-Ray Measurements in Instruments," by Robert Gager, Victoreen Instrument Corporation; September 19, 1950.

"Man and Computer," by G. L. Landsman, Bureau of Standards; October 17, 1950.

Atlanta

Business Meeting; June 30, 1950.

"The Conduct of the Business of The Institute of Radio Engineers," by Ben Akerman, Regional Director, Region 6; September 29, 1950.

Baltimore

"FM versus AM for VHF Marine Communication," by L. W. Lynn, General Electric Company; October 11, 1950.

Beaumont-Port Arthur

Films: "Stepping Along With Television," and "Telephone Screen Review"; September 22, 1950.

"Industrial Radar for Tracking Hurricanes," by A. T. Deere, Dow Chemical Company; October 4, 1950.

Boston

"The Digital Computer as an Information Processing System," by J. W. Forrester, Massachusetts Institute of Technology; September 28, 1950.

Buffalo-Niagara

"Electronics in Defense Against Atomic Attack," by Seville Chapman, Faculty, Cornell Aeronautic Laboratory; September 20, 1950.

Cedar Rapids

"A Sixty-Six Million Electron Volt Proton Linear Accelerator," by W. G. Shepherd, Faculty, University of Minnesota; September 26, 1950.

Cincinnati

"Photo Electric Organ," by Ted Jones, Baldwin Company; September 19, 1950.

Cleveland

Informal Meeting; September 29, 1950.

Connecticut Valley

"Recording and Reproduction of LP Microgroove Records," by W. S. Bachmann, Columbia Records, Inc.; "A Wideband Cathode Follower," by William Von Winkle, Graduate Student, Yale University; September 21, 1950.

Dallas-Fort Worth

"1000 Ft. TV-FM Antenna," by Stuart Wilson, International Derrick Company; September 29, 1950.

Denver

"Cosmic Ray Research on Mt. Evans," by Mario Iona, Faculty, University of Denver; October 13, 1950.

Emporium

"Instrumentation in Modern Geophysics," by R. D. Wycoff, Gulf Oil Company; September 22, 1950.

Evansville-Owensboro

"A New Three Tube Single Side Band Transmitter," by D. E. Norgaard, General Electric Company; September 20, 1950.

"Test Equipment for Pulse, EHF, UHF, VHF, and Audio Frequencies," by Frank Waterfall, Alfred Crossley Associates; October 11, 1950.

Houston

"Computations and Measurements on RF Transmission Lines," by C. V. Clarke, Radio Station KPRC-KXYZ; October 17, 1950.

(Continued on page 40A)

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Now, the Potter Instrument Company offers all-in-one equipment, the features heretofore available only in separate counting systems. Two complete counting channels, a 100 kc crystal oscillator time base and unique gating circuits are combined to provide the new FREQUENCY-TIME COUNTER.

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SECTION MEETINGS

(Continued from page 38A)

INDIANAPOLIS

"Lecture and Demonstration of Test Equipment for Pulse, UHF and Audio Measurements," by Frank Waterfall, Alfred Crossley and Associates; October 12, 1950.

KANSAS CITY

"Industry Report"; January 24, 1950.

"The Interaction of Electrons and Electromagnetic Field Multicavity," by Chai Yeh, Faculty, University of Kansas; February 15, 1950.

Student Paper Competition; April 11, 1950.

"Solar and Cosmic Noise," by C. R. Burrows, Faculty, Cornell University; Election of Officers; May 5, 1950.

"Television Network Facilities of the Bell System," by M. E. Strieby, American Telephone and Telegraph Company; September 21, 1950.

"Flush Mounted Travelling Wave Antennas," by D. K. Reynolds, Faculty, Stanford Research Institute; September 22, 1950.

LOS ANGELES

"Co-Channel Sky Wave Recording," by Mal Mobley, Jr., Radio Station KMPC; "Automatic Methods in Ultrasonic Flaw Detection," by George Greene and Don Erdman, Electro-circuits Company; "Electronics in the Chemical Industry," by Howard Carey, Applied Physics Corporation; October 3, 1950.

MILWAUKEE

"More Waves—More Words—Less Wire," by Dr. Perrine, American Telephone and Telegraph Company; September 20, 1950.

NEW MEXICO

"Airborne Antennas," by H. A. Schutz, Glenn L. Martin Company; August 25, 1950.

"The Mathematical Training of Electrical Engineers," by Alexander Boldyreff, Faculty, University of New Mexico; September 22, 1950.

NEW YORK

"The Engineer's Approach to the Human Mechanism," by J. R. Ragazzini, Faculty, Columbia University; September 6, 1950.

NORTH CAROLINA-VIRGINIA

"Television Planning, Installation, and Proof of Performance Test," by W. L. Braun, Radio Station WSEA; September 29, 1950.

OTTAWA

"Importance of the Loudspeaker in Sound Reproduction," by G. J. Thiesen, Acoustics Laboratory, N.R.C.; October 19, 1950.

PHILADELPHIA

Business and Social Meeting; October 5, 1950

PORTLAND

"The Growth of Professional Groups to More Effectively Disseminate Information on Institute Affairs," by A. V. Eastman, Regional Director, The Institute of Radio Engineers; May 5, 1950.

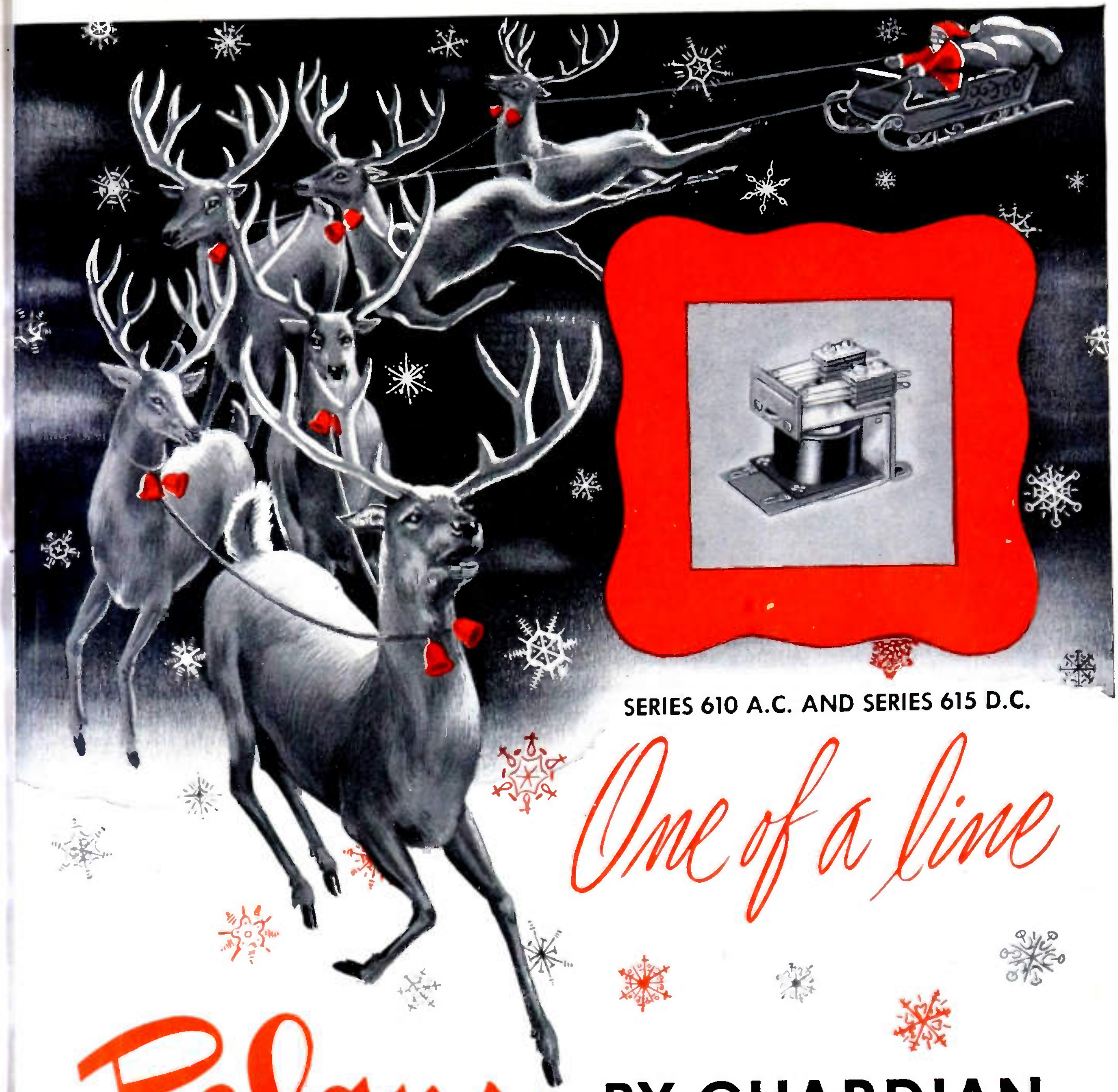
"Metal Plate Lenses for Microwave," by J. J. Brady, Faculty, Oregon State College; May 20, 1950.

"Modern Transmission Methods in Electrical Communication," by Ralph Bown, Bell Telephone Laboratories; May 22, 1950.

"Design of a Regulated Frequency Power Supply for Use in Bell System Time Announcing Machines," by H. M. Owendoff, Bell Telephone Laboratories; June 22, 1950.

"BPA Microwave System," by D. E. Smith, Bonneville Power Administration; "FTL Equipment," by N. J. Gottfried, Federal Telecommunications Laboratories; Inspection Tour conducted by R. J. Hughes, Federal Telecommunications Laboratories; September 21, 1950.

(Continued on page 42A)



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SECTION MEETINGS

(Continued from page 40A)

"Signalling Equipment Used in Long Distance Automatic Dialing," by L. B. Edwards, Pacific Telephone and Telegraph Company; October 19, 1950.

Salt Lake

"Type K Carrier System," by W. M. Stuart, American Telephone and Telegraph Company; Tour of KSL-TV Studios; October 16, 1950.

San Antonio

"Relationship of the Regional Director to the Sections," by Ben Akerman, Radio Station WGST; "Microwave Atmospheric Refractometer," by A. P. Deam, Faculty, University of Texas; September 21, 1950.

San Diego

"Guided Missile Electronics," by D. P. Tucker, U. S. Navy Electronics Laboratory; September 5, 1950.

Schenectady

"Electronics in Navigation Control," by R. L. Wanamacher, General Electric Company; October 2, 1950.

Seattle

"Control of Loudspeaker Bass Response," by W. R. Hill, Faculty, University of Washington; September 29, 1950.

Syracuse

"The Bell Telephone Laboratory and Its Work," by J. W. McRae, Bell Telephone Laboratories; October 5, 1950.

Toledo

Films: "Mobile Telephone" and "Radar and Sonar," by Ohio Bell Telephone Company; September 12, 1950.

Toronto

"Master Control Equipment for a Large Broadcasting Studio Center," by R. H. Tanner, Northern Electric Company; October 2, 1950.

Vancouver

"Institute Affairs," by A. V. Eastman, Faculty, University of Washington; Election of Officers; September 19, 1950.

Washington

"A New Coupling Circuit for Audio Amplifiers," by F. H. McIntosh, McIntosh Engineering Laboratory, Inc.; October 9, 1950.

Williamsport

"Television Synchronizing Circuits," by N. S. Kornetz, Westinghouse Radio Division; September 27, 1950.

Subsections

Amarillo-Lubbock

"Vertical Antennas," by George McBride, Radio Station KFDA; May 23, 1950.

"Noise Figure Measurements," by J. E. Masterson, Faculty, Texas Technological College; September 6, 1950.

Binghamton

"Radio Shielding, Principles and Practice," by C. F. Maylott, Bendix Corporation; September 28, 1950.

Centre County

"Radar in the Next War," by G. L. Haller, Faculty, Pennsylvania State College; Election of Officers; May 22, 1950.

"The Polarimeter, Its Use in Studying Low Frequency Echoes," by H. J. Nearhoff, Radio Propagation Laboratory; "Relays: Their Place in the Modern Power System," by L. G. McCracken, Faculty, Pennsylvania State College; October 17, 1950.

(Continued on page 44A)

SECTION MEETINGS

(Continued from page 42A)

HAMILTON

"Practical Design Considerations in Synch and Sweep Circuits," by N. S. Kornetz, Westinghouse Electric Corporation; September 18, 1950.

"Mission, Organization and Function of RCAF Telecommunications," by E. A. D. Hutton, Royal Canadian Air Force; October 16, 1950.

LANCASTER

"Magnetic Tape Recording Principles," by R. H. Ranger, Ranger Tone Corporation; October 11, 1950.

MONMOUTH

"The Engineer's Approach to the Human Mechanism," by J. R. Ragazzini, Faculty, Columbia University; September 27, 1950.

NORTHERN NEW JERSEY

"Color Television," by A. G. Jensen, Bell Telephone Laboratories; September 13, 1950.

"A 20 Cycle to 50 Megacycle Signal Generator," by J. M. van Beuren, Measurements Corporation; "Notes on Measurement of Phase Distortion," by D. M. Hill, Boonton Radio Corporation; "Recent Developments in Cathode-Ray Oscillography," by P. S. Christaldi, Allen B. Dumont Laboratories, Inc.; October 11, 1950.

STUDENT BRANCH MEETINGS

UNIVERSITY OF ARKANSAS, IRE BRANCH

Election of Officers; September 27, 1950.

"Geiger Counters," by Paul Damon, Faculty, University of Arkansas; October 11, 1950.

BUCKNELL UNIVERSITY, IRE-AIEE BRANCH

"Structure and Functions of the IRE," by B. H. Bueffel, Jr., Faculty, Bucknell University; "Piezo-electric Crystals," by E. J. Prokop, Student, Bucknell University; September 28, 1950.

UNIVERSITY OF CALIFORNIA, IRE-AIEE BRANCH

"The Amazing Universe," by L. E. Reukema, Faculty, University of California; September 21, 1950.

"Opportunities in Professional Societies," by J. R. Whinnery and J. Fahey, Faculty, University of California; October 10, 1950.

CARNEGIE INSTITUTE OF TECHNOLOGY, IRE-AIEE BRANCH

"Qualities I Look for in Employing Engineers," by Edward Beck, Westinghouse Corporation; September 28, 1950.

"The Present Status of Color Television," by J. T. Holland, Jr., Student, Carnegie Institute of Technology; October 3, 1950.

"Electrical Engineering as a Profession," by B. R. Teare, Faculty, Carnegie Institute of Technology; October 10, 1950.

CLARKSON COLLEGE, IRE BRANCH

"Advantages of The Institute of Radio Engineers," by F. A. Record, Faculty, Clarkson College of Technology; October 5, 1950.

Films; "Unseen Worlds," and "Radio at War"; October 19, 1950.

(Continued on page 46A)

STUDENT BRANCH MEETINGS

(Continued from page 44A)

University of Colorado, IRE-AIEE Branch

"Introduction to the AIEE," by C. DuVall, Faculty, University of Colorado; Films; "Turbo-Jet Propulsion," and "Seeing at Home"; October 3, 1950.

University of Connecticut, IRE-AIEE Branch

"Television," by G. W. Ray, Radio Station WNHC; October 5, 1950.

Cooper Union, IRE Branch

Business Meeting; and Election of Officers; October 3, 1950.

Cornell University, IRE-AIEE Branch

"Progress in Better Living," by L. P. Shannon, E. I. DuPont de Nemours and Company; October 6, 1950.

University of Denver, IRE-AIEE Branch

Business Meeting; October 5, 1950.

Business Meeting; Film: "Quartz Crystals"; October 17, 1950.

University of Florida, IRE-AIEE Branch

"What You Don't Know, May Hurt You," by E. D. Whittlesey, Faculty, University of Florida; October 3, 1950.

University of Kentucky, IRE Branch

"Quality Control in Manufacturing," by C. C. Jones, General Electric Company; October 12, 1950.

Lafayette College, IRE-AIEE Branch

"VHF Omnidirectional Radio Range," by R. H. Wilcox, Student, Lafayette College; October 10, 1950.

Marquette University, IRE-AIEE Branch

Business Meeting; and Election of Officers; October 5, 1950.

University of Maryland, IRE-AIEE Branch

Discussion by Students; and Election of Officers; October 18, 1950.

Massachusetts Institute of Technology, IRE-AIEE Branch

"Industrial Organization," by Mr. Powell, Faculty, Massachusetts Institute of Technology; November 7, 1949.

"Boston's New Telephone Company Building," by W. F. Potter, Bell Telephone System; November 21, 1949.

Inspection Trip of New Telephone Building; November 22, 1949.

"Electrostatic Generators in Industry," by E. A. Burrill, High Voltage Engineering Corporation; December 8, 1949.

"MIT Center of Analysis," by S. Caldwell, Faculty, Massachusetts Institute of Technology; January 16, 1950.

"Electrostatic Precipitation," by Mr. Price, Raytheon Manufacturing Company; February 20, 1950.

Slides shown by Frank Doble, Doble Engineering Company; March 13, 1950.

"Some General Considerations in Audio System Design," by John Kessler, Faculty, Massachusetts Institute of Technology Acoustics Laboratory; March 20, 1950.

"50-920 MCPS Standard Signal Generator," by Erwin Gross, General Radio Company; April 17, 1950.

"Light Magic," by L. S. Cooke, General Electric Company; Nomination of Officers; May 1, 1950.

(Continued on page 48A)

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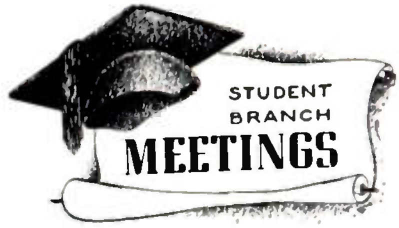

(*Continued from page 46A*)

Election of Officers; September 27, 1950.

"Personnel and Organization of Radio and Television Stations," by S. V. Stadig, Radio Station WBZ-TV; October 9, 1950.

UNIVERSITY OF MICHIGAN, IRE-AIEE BRANCH

"The Engineer in the Field of Management," by P. W. Thompson, Detroit Edison Company; October 3, 1950.

MISSOURI SCHOOL OF MINES & METALLURGY, IRE-AIEE BRANCH

"Engineering Contributions to the Medical Sciences," by J. T. Wilson, Allis-Chalmers Company; September 28, 1950.

"Recent Developments in Missouri's Electric Utilities," by James Stephen, Missouri Public Service Corporation; October 12, 1950.

NEW MEXICO COLLEGE OF AGRICULTURE & MECHANIC ARTS, IRE-AIEE BRANCH

"The Aerobee Rocket," by G. H. Fesselman, Physical Science Laboratory; September 21, 1950.

COLLEGE OF THE CITY OF NEW YORK, IRE BRANCH

Business Meeting; Film: "Rotating Magnetic Fields"; September 28, 1950.

"Power Generation and Transmission," by Harold Baumann, Consolidated Edison Company; October 5, 1950.

NEW YORK UNIVERSITY, IRE BRANCH (DAY DIVISION)

"Analog Computers," by Milton Gerber, Reeves Instrument Company; June 7, 1950.

"Japanese Engineering Education," by Professors Cato, Watanabe, and Asami; September 28, 1950.

Business Meeting; October 5, 1950.

"Jobs Available to Young Engineering Graduates," by W. G. Denning, Consolidated Edison Company; October 19, 1950.

NORTHEASTERN UNIVERSITY, IRE-AIEE BRANCH

"Lightning," by C. L. Dawes, Faculty, Harvard University; September 21, 1950.

Field Trip to Radio Station WBZ-TV; September 26, 1950.

Films: "Where Shall You Hide," "One World or None," and "Atomic Energy"; October 3, 1950.

OHIO STATE UNIVERSITY, IRE-AIEE BRANCH

"Experiences of a Campus Publication Advisor," by W. R. Dumble, Faculty, Ohio State University; October 12, 1950.

OREGON STATE COLLEGE, IRE BRANCH

"The IRE and AIEE and Student Engineers," by F. O. McMillan, Faculty, Oregon State College; September 28, 1950.

"Vibration in Transmission Line Conductors," by R. F. Steidel, Faculty, Oregon State College; October 12, 1950.

PENNSYLVANIA STATE COLLEGE, IRE-AIEE BRANCH

Introduction of Officers; September 21, 1950.

PRATT INSTITUTE, IRE BRANCH

"Distribution Engineering," by Charles Metcalfe, Consolidated Edison Company; October 11, 1950.

RENSSELAER POLYTECHNIC INSTITUTE, IRE-AIEE BRANCH

"Advantage of a Professional Society—Job Interviews," by E. S. Lee, General Electric Consulting Laboratory; October 18, 1950.

(*Continued on page 49A*)

Student Branch Meetings

(Continued from page 48A)

Rhode Island State College, IRE-AIEE Branch

Business Meeting; September 26, 1950.

"Implications of New FCC Ruling for Color Television," by W. B. Hall, Faculty, Rhode Island State College; October 19, 1950.

Rutgers University, IRE-AIEE Branch

Film: "Adventures in Research"; October 10, 1950.

University of Southern California, IRE-AIEE Branch

Business Meeting; "The Preparation and Presentation of Student Papers," by R. M. Strassner; September 28, 1950.

Syracuse University, IRE-AIEE Branch

Election of Officers; Film: "1949 Syracuse-Colgate Football Game"; September 28, 1950.

University of Texas, IRE-AIEE Branch

"Zurich Radio Conference," by A. W. Straiton, Faculty, University of Texas; October 16, 1950.

Tufts College, IRE-AIEE Branch

"Professional Societies," by A. H. Howell, Faculty, Tufts College; October 4, 1950.

University of Wyoming, IRE-AIEE Branch

"Organization, Purpose and Aims of AIEE," by W. C. DuVall; October 5, 1950.

The following transfers and admissions were approved and will be effective as of December 1, 1950:

Transfer to Senior Member

Beusman, R. M., 1212 Woodbine Ave., Oak Park, Ill.
Capodanno, R. T., 50 Coolidge Ave., W. Caldwell, N. J.
Chapman, J. K., 329 Westvale Rd., Syracuse 9, N. Y.
Farr, K. E., R. D. 1, Box 193A, Paxinos, Pa.
Forster, W. H., 920 E. Mt. Airy Ave., Philadelphia 19, Pa.
Hansen, W. W., 8819 S. Talman Ave., Chicago 42, Ill.
Hargens, C. W., III, 909 Hunters Lane, Enfield, Oreland P. O., Pa.
Henderson, A. B., 801 Hathaway Rd., Dayton 9, Ohio
Horvath, A., 212 Harding Ave., Clifton, N. J.
Ittelson, R. W., 551 Daytona Pkwy., Dayton 6, Ohio

Keachie, J. H., RCA Victor Division, 718 Keith Bldg., Cleveland 15, Ohio
McClellan, C. E., 1306 Tarrant Rd., Glen Burnie, Md.
Murphy, J. L., 1456 E. 54 St., Chicago 15, Ill.
Rambo, S. I., 154 Oaklee Village, Baltimore 29, Md.
Reid, J. G., Jr., 2929 Connecticut Ave., N.W., Washington, D. C.
Ritter, E. H., Northrop Aircraft, Inc., Hawthorne, Calif.
Senn, G. F., 81 Garden Rd., Little Silver, N. J.
Stoker, W. C., Brunswick Rd., Rt. 57, Troy, N. Y.
Swanson, M. W., 8704 Maywood Ave., Rosemary Hills, Silver Springs, Md.

(Continued on page 62A)

POSITIONS OPEN

The following positions of interest to I.R.E. members have been reported as open. Apply in writing, addressing reply to company mentioned or to Box No. ...

The Institute reserves the right to refuse any announcement without giving a reason for the refusal.

PROCEEDINGS of the I.R.E.
1 East 79th St., New York 21, N.Y.

PROJECT ENGINEERS

Five years or more experience in charge of design and development of radio and communication equipment. Must be graduate of a credited engineering school. Well equipped laboratory in modern radio and television plant, with excellent opportunities for advancement. Send resume of qualifications to Mr. S. F. Cascio, Personnel Director, Hallicrafters Co., 4401 West Fifth Ave., Chicago 24, Ill.

ENGINEERS

A very large vacuum tube and cathode ray tube manufacturer has attractive openings for experienced vacuum tube engineers. It will be to your benefit to investigate these possibilities. Please write to Box 628.

SENIOR ELECTRONIC ENGINEER

Opportunity with manufacturer of electronic electro-mechanical and radiation instruments. Requirements: 5 years experience in design and development of pulse circuits, computers, nuclear instrumentation or video circuits required. Manufacturing or production experience desirable. Send complete resumes and salary requirement to: Berkeley Scientific Company, P.O. Box 1826, Richmond, Calif.

PRODUCTION ENGINEER

Opportunity with manufacturer of electronic, electro-mechanical and radiation instruments. Requirements: 5-10 years experience as electronic and mechanical instrument production engineer in small lot production. Thorough electronic theory grounding. Send complete resume and salary requirements to Berkeley Scientific Co., P.O. Box 1826, Richmond, Calif.

ELECTRICAL ENGINEER

Graduate with experience in design and product technique of specialized electronic tubes other than high production transmitting and receiving types. Bendix Aviation Corp., Kansas City Division, P.O. Box 1159, Kansas City, Missouri.

ELECTRONIC ENGINEER

Excellent opportunities are offered by one of the leading concerns in the electronic computer field to engineers with development or design experience in video and pulse circuitry or test and maintenance experience in the radar television or computer fields. Send complete information to Personnel Dept., Eckert-Mauchly Computer fields. Send complete information to 32, Pa.

ELECTRONIC ENGINEERS

Electronic engineers with a background in patent specification writing desired for an expanding Patent Dept. in a growing

(Continued on page 51A)

ELECTRONICS TECHNICIANS WANTED

The RCA Service Company, Inc., a Radio Corporation of America subsidiary, needs qualified electronics technicians for U. S. and overseas assignments. Candidates must be of good character and qualified in the installation or maintenance of RADAR or COMMUNICATIONS equipment or TELEVISION receivers. No age limits, but must have at least three years of practical experience.

RCA Service Company offers comprehensive Company-paid hospitalization, accident and life insurance programs; paid vacations and holidays; periodic review for salary increases; and opportunity to obtain permanent position in our national and international service organization, engaged in the installation and maintenance of AM, FM, and TV transmitters, electronic inspection devices, electron microscopes, theatre and home television, r-f heating equipment, mobile and microwave communications systems, and similar electronic equipment.

Base pay, overseas bonus, payments for actual living and other expenses, and benefits mentioned above add up to $7,000 per year to start for overseas assignments, with periodic review of base salary thereafter. Openings also available at proportionately higher salaries for specially qualified technicians with supervisory ability.

Qualified technicians seeking an advantageous connection with a well-established company, having a broad-based, permanent peacetime and wartime service program, write to:

Mr. G. H. Metz,
Personnel Manager,
RCA Service Company, Inc.,
Camden 2, New Jersey.

POSITIONS OPEN

(Continued from page 50A)

research and development organization located in the midwest. Unlimited opportunity for advancement for properly qualified men. Law degree unnecessary. Must be U. S. citizen and free to make occassional trips to Washington D. C. Please give full details in first letter. Box 630.

ELECTRONIC ENGINEER

Senior graduate engineer with at least 10 years experience in receiver design. Minimum of 2 years experience UHF desirable. Must be capable of assuming project responsibility. Location Connecticut. Excellent opportunity. Salary high Submit resume. Box 631.

ELECTRONIC ENGINEERS

The U. S. Naval Ordnance Experimental Unit is located at the National Bureau of Standards, Washington, D.C. The following vacancies exist in grades GS 14, $8800, GS 13, $7600 and others of Electronic Engineers (General) (Radar) (Instrumentation) and (Stabilization). Assignments will include consultation, evaluation and product engineering in the development of guided missile components. Enclose copy of Civil Service Application Form 57 (obtainable at local post office) and address completed form to Officer in Charge, U. S. Naval Ordnance Experimental Unit, National Bureau of Standards, Washington 25, D.C.

ELECTRONIC ENGINEER

Electronic engineer with interest in instrumentation and automatic control to join instrument development group at the Wind Tunnels Laboratory. Starting salary $3100-$3825 per annum. Apply Civilian Personnel Division, Aberdeen Proving Ground, Maryland.

ENGINEER

Small California transmitting tube company requires engineer for medium frequency tube work, also for development and manufacture of klystrons and pulse tubes. Give full details giving age, experience, availability and salary expected. Box 632.

ENGINEERS AND PHYSICISTS

Project and senior engineers desired for work on several theoretical and experimental programs of diversified nature involving military applications of electronics. Applicants should have 3 or more years of experience in research and development in some branch of electronics and preferably advanced graduate training. Command of physical fundamentals and analytical ability important. Small, expanding company located in college town. Opportunities of graduate study. Reply Personnel Manager, Haller, Raymond and Brown, Inc. State College, Pa., stating education, experience, salary expected.

ENGINEERS

National Broadcasting Company needs experienced engineers with commercial television operating experience or standard broadcasting control room experience. Apply Room 505, 30 Rockefeller Plaza, New York, N.Y.

(Continued on page 52A)

The W. L. MAXSON CORPORATION

IS

SEEKING

Outstanding

ENGINEERS

AND

PHYSICISTS

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AMBITION

TO

FURTHER PRESENT STANDING

Immediately

Minimum Requirements are:

1. Five to ten years experience in advanced electronic research and development
2. Outstanding record of ingenuity
3. Ph.D., M.S. or equivalent

Please send résumé and salary requirements to:

The W. L. MAXSON CORPORATION
460 W. 34th St.
New York 1, N.Y.

ELECTRICAL ENGINEERS

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Independent industrial research and development laboratory has openings for electrical engineers with training and experience in the following fields: UHF; Instrumentation; Telemetering; Computers; Servo and Control Systems; and Electromagnetic Devices.

Candidates should have an excellent scholastic record. Advanced degree helpful, but not essential. Requires 2-5 years experience, with record of accomplishment in one or more of the above fields.

Good salaries for outstanding men plus other benefits—such as a retirement plan (immediate vesting), group insurance, and nearby opportunities for graduate work. Excellent opportunities for advancement.

Write, giving survey of qualifications, to

Electrical Engineering Research
ARMOUR RESEARCH FOUNDATION of
ILLINOIS INSTITUTE OF TECHNOLOGY
Technology Center
Chicago 16, Illinois

PHYSICISTS, ENGINEERS APPLIED MATHEMATICIANS

Electronic and mechanical engineers, physicists and applied mathematicians.

POSITIONS AVAILABLE AT ALL LEVELS

for research and development in radar, microwaves, servo systems, computers, telemetering, instrumentation and nucleonics.

Permanent positions offering variety, responsibility, and challenging opportunities for advancement.

BENDIX AVIATION CORPORATION
RESEARCH LABORATORIES
4855 Fourth Avenue
Detroit 1, Michigan

POSITIONS OPEN

(Continued from page 51A)

ELECTRON TUBE ENGINEERS

For development and production. Experience miniature or sub-miniature tubes desirable. Apply by letter only to Personnel Dept., Sonotone Corp., Elmsford, New York.

RADIO AND TELEVISION ENGINEERS

Experienced in design of high frequency circuits such as FM tuners, TV boosters and TV antennae. Salary commensurate with ability. Write giving full details—Mr. Stone, Talk-A-Phone Company, 1512 South Pulaski Rd., Chicago 23, Ill. Lawndale 1-8414.

ENGINEERS

Physicists, chemists or EE's with PhD or equivalent and experience in the field of solid state physics for research work on semi-conductor devices employing germanium and silicon. An excellent opportunity in a research laboratory of a leading manufacturer with laboratories in New York state. Send complete resume. Our employees have been notified. Box 633.

SENIOR ELECTRONICS ENGINEER

For design and development of circuitry for ultrasonic equipment timing circuits, audio oscillators amplifiers, and audio measuring equipment to meet Navy specifications. Experience required: 3-5 years in development of audio or supersonic equipment for government or industrial usage. Must have B.S. in physics or electrical engineering. Write: Personnel Director, Box 30, State College, Pa.

DEVELOPMENT TECHNICIANS

At least 3 years experience in layout. (Including rough drafting) of electronic chassis. Should also be experienced in electronics testing and trouble shooting. Write: Personnel Director, Box 30, State College, Pa.

ELECTRICAL ENGINEER

Graduate electrical engineer with a minimum of 2 years' experience. For design and development of audio transformers and filters. Permanent position with progressive firm located in Chicago. Give details stating age, education, experience, references, availability for work and salary expected. Box 634.

ENGINEERS

The 15th Naval District which comprises the Panama Canal Zone is in need of electronic engineers, electronics draftsmen, radio and electronic mechanics. Employment is with the Navy. No Civil Service status is required for these positions in Canal Zone. Rates pay as follows: Engineers—$5750-$6650. Draftsmen—$4300-$5250. Mechanics—$2.02-$2.23 per hour. Employment under an 18 month agreement which provides transportation with shipment of household effects to and from the home of employee and is subject to indefinite renewal. Apply: Commandant, 15th Naval Dist. (District Civilian Personnel Office) Box 127, Fort Amador, Canal Zone.

ELECTRONIC SCIENTIST

For research in upper atmosphere rocket program. Must have an appropriate de-

(Continued on page 54A)

Graduate ENGINEERS

Good Opportunities for ELECTRONICS

Engineers or Physicists

M.S. or Ph.D. in Physics, Physical Chemistry, E.E., M.E., or Ch.E. for industrial electronics research. Must be outstanding technically with at least a few years research experience, and interested in the development of instruments and physical techniques.

Give experience, education, age, references, personal history, salary received and salary expected. Please be complete and specific.

All inquiries will be considered promptly and kept confidential.

E. I. du Pont de Nemours & Co. (Inc.)
Engineering Department Personnel
Wilmington 98, Delaware

RESEARCH ENGINEERS ELECTRICAL ENGINEERS AND PHYSICISTS

THE FRANKLIN INSTITUTE LABORATORIES FOR RESEARCH AND DEVELOPMENT

Have opening for personnel with 2-10 years experience. Advanced degrees are desirable in certain of the positions. Fields of interest covered are: Mathematical Analysis of Physical Problems, Statistical Theory of Communications, Electromagnetic Theory, Circuit Analysis, Servomechanism Theory, Electrical Computing, Advanced and Fundamental Circuit Development, Radar and Pulse Circuits, Supervision of Operation of G.C.A. or Tracking Radar, Air Traffic Control, Air Navigation, Automatic Controls, Industrial or Marine Power Drives, and Electrical Machinery.

Send resume of education and experience, salary requirements and a photograph to:

Personnel Department
THE FRANKLIN INSTITUTE
Philadelphia 3, Pennsylvania

POSITIONS OPEN

(Continued from page 52A)

gree, and at least 3 years experience, with emphasis on electronics as applied to upper atmosphere research or an allied field. Please address replies, containing a brief resume of experience to Employment Officer, Naval Research Laboratory, Washington 25, D.C.

RADIO & RADAR ENGINEERS

Radio and radar engineers for aircraft installation and application design work. Should have 5 or more years' experience with aircraft radio or radar systems, and preferably have aircraft installation or antenna design, selection and application experience. Experienced aircraft electrical engineers are also needed. Contact Engineering Personnel Section, Chance Vought Aircraft, P.O. Box 5907, Dallas, Texas.

ELECTRONIC ENGINEER

Electronic engineer to head engineering department. Must have had experience in development and design of quartz crystals for frequency control and thorough knowledge of manufacturing processes. Box 636.

Positions Wanted By Armed Forces Veterans

In order to give a reasonably equal opportunity to all applicants, and to avoid overcrowding of the corresponding column, the following rules have been adopted:

The Institute publishes free of charge notices of positions wanted by I.R.E. members who are now in the Service or have received an honorable discharge. 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.

COMMUNICATIONS ENGINEER

B.S.E.E. September 1950, Ohio State University. Married, age 25. 6 years AM and FM broadcasting experience. Chief Engineer overseas Armed Forces radio station 8 months. 1st class radio-telephone license. Desires production or design. Box 476 W.

ELECTRICAL ENGINEER

B.S.E.E. Kansas State College, January 1950. Eta Kappa Nu, I.R.E. Age 29, married. Aircraft electrician, Army radar. Interested in sales, design or development of electronic equipment. Location and salary secondary. Box 478 W.

(Continued on page 55A)

COIL ENGINEER

Large manufacturer of radio and television receivers has an opening for an experienced coil engineer to design RF and IF coils for mass production.

Should have a thorough background in coil application and coil manufacturing techniques. Send complete resume giving education, experience, age, and salary requirements.

Box No. 637
THE INSTITUTE OF RADIO ENGINEERS
1 East 79th St., New York 21, N.Y.

Positions Wanted

(Continued from page 54A)

ELECTRONICS INSTRUCTOR

Nine years servicing civilian and government RXs, and TXs and PA systems; 6 years teaching AM, FM and TV mathematics, theory and laboratory; 2 years Navy radar training. Last positions: organized school technically and held chief instructors status 3 years. Box 479 W.

ELECTRONIC ENGINEER—PHYSICIST

Six years of physics, electrical engineering and electronics in Fordham, University of Rochester, Harvard, Massachusetts Institute of Technology and Brooklyn Polytechnical Institute: B. S. in Physics, June 1949. 1½ years servomechanism development plus 3 years as Naval electronics officer. Age 27, married, 2 children. Desires position in electrical engineering, technical or sales anywhere in U. S. or overseas. Box 480 W.

ELECTRICAL ENGINEER

Recent electrical engineering graduate. Some experience. Special interest in design of VHF communications equipment, propagation studies or field surveys, and evaluation of overall system performance. Desires position continental U.S.A. Box 481W.

ELECTRONIC ENGINEER

B.E.E. June 1949, University of Delaware, Age 25, married. 3½ years Navy AETM. 1 year in nucleonic instrument maintenance, calibration, and modification. Desires research or development position in New York or Philadelphia area. Box 482 W.

(Continued on page 58A)

RESEARCH ENGINEERS

CALIFORNIA INSTITUTE OF TECHNOLOGY JET PROPULSION LABORATORY, PASADENA CALIFORNIA

Needs Research Engineers for work on their Missile Program in the following electronic categories:

RADAR
ANTENNAS
TELEMETERING
COMPUTERS
INSTRUMENTATION
ANALOG COMPUTERS

Apply in writing and furnish information as to education and experience. 4800 Oak Grove Drive, Pasadena 3, California.

TECHNICAL EDITORS AND WRITERS

These are senior positions, the men selected must be able to outline, compile, edit, proofread, plan and check art, dummy, and direct the final publication of technical and scientific publications.

A good working knowledge of radio and radar theory and application is essential, in addition to extensive editorial and journalistic experience. Some knowledge of structural and mechanical engineering is desirable.

Send complete resume with first letter to:

James E. Thompson
Department 29
HUGHES AIRCRAFT COMPANY
Culver City, California

All replies will be handled in the strictest confidence

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for

challenging research and advanced development in fields of

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PRECISION MECHANICAL DEVICES
ELECTRICAL SYSTEM DESIGN
GENERAL ELECTRONICS
INSTRUMENTATION
MICROWAVES
COMPUTERS
AUTOPILOTS

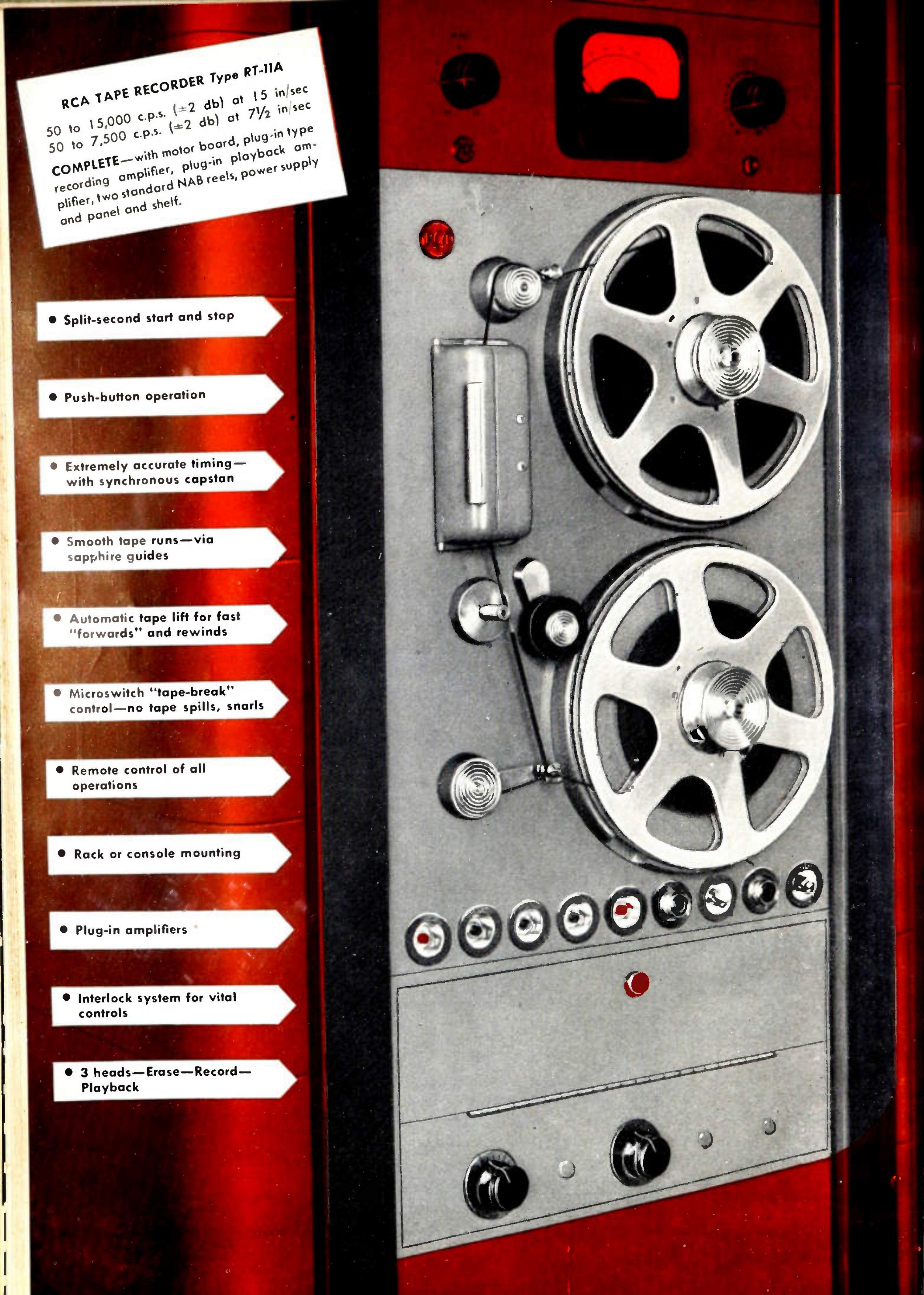
Scientific or engineering degree and extensive technical experience required.

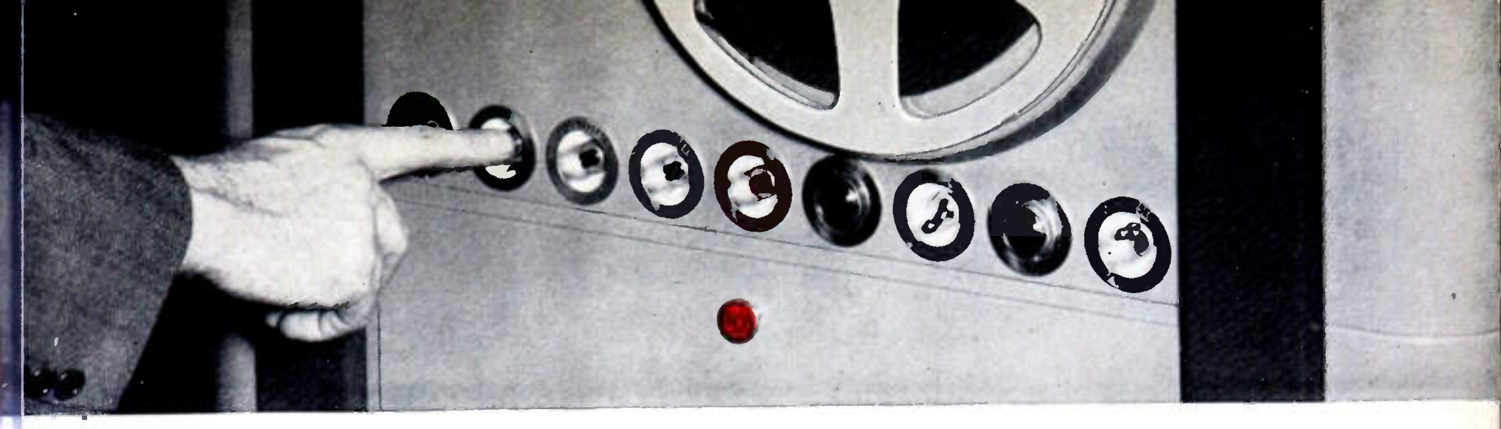
WRITE:
Manager, ENGINEERING PERSONNEL
BELL AIRCRAFT CORPORATION
P.O. Box 1, Buffalo 5, N.Y.

PHYSICISTS AND ENGINEERS

You can find plenty of positions where you will work on minor improvements on radar, telemetering systems, and other conventional devices. However, you will find very few positions where you can break ground in new fields having tremendous significance. This you can do at the JACOBS INSTRUMENT COMPANY, whose entire effort is devoted to pioneering activities in new fields that it has opened up itself. One of these fields, for example, is that of ultra-high speed, ultra-compact digital computers and controllers. This company's JAINCOMP family of computers dominates this field. Other equally important fields are being developed. Engineers and physicists with sound backgrounds and experience in the design of advanced electronic circuits or precision mechanical instruments may qualify, also individuals with good backgrounds in applied physics. A few openings exist for outstanding junior E. E.'s and physicists, also experienced technicians; applicants for these positions must apply in person.

JACOBS INSTRUMENT CO.
4718 Bethesda Ave.
Bethesda 14, Maryland


RCA TAPE RECORDER Type RT-11A
50 to 15,000 c.p.s. (±2 db) at 15 in/sec
50 to 7,500 c.p.s. (±2 db) at 7½ in/sec
COMPLETE—with motor board, plug-in type recording amplifier, plug-in playback amplifier, two standard NAB reels, power supply and panel and shelf.
Split-second start and stop
Push-button operation
Extremely accurate timing—with synchronous capstan
Smooth tape runs—via sapphire guides
Automatic tape lift for fast "forwards" and rewinds
Microswitch "tape-break" control—no tape spills, snarls
Remote control of all operations
Rack or console mounting
Plug-in amplifiers
Interlock system for vital controls
3 heads—Erase—Record—Playback

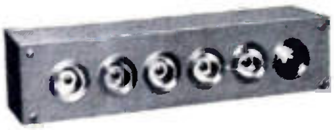


USH-BUTTON CONTROL puts tape recording facilities at your fingertips.

NEW–

High-Fidelity Tape Recorder

–the finest money can buy!



emote Control Unit, MI-11948. Available extra.

This is the world's foremost professional tape recorder, the one recorder that has *everything*—accurate timing, ow wow and flutter, plus quick starting. All operations ıre push-button controlled. All functions—including :ueing—can be extended to remote positions.

Designed for applications where operating TIME ınd RELIABILITY are prime factors, the new Type RT-11A Recorder offers a number of exclusive features. For example, you can start or stop the tape in 0.1 second. You can jockey the tape back and forth for cueing with- out stopping. You can rewind a standard 10½-inch reel n one minute!

A synchronous capstan makes it practical to hold recording time to ±2½ seconds in a 30-minute run. And with synchronizing equipment . . . for which provision is made . . . *timing can be held to 0.3 second on any length program!*

Many more important features, too.

Self-centering "snap-on" hub adaptors assure perfect reel alignment with either RMA or NAB reels. A complete system of control interlocking virtually eliminates the possibility of accidentally erasing a program—makes it impossible to snarl or "spill" the tape. "Microswitch" control stops the machine if the tape is severed—applies reel brakes instantaneously. The tape automatically lifts *free and clear* of heads during fast forward runs or rewinds. Tape alignment over the heads is held precisely by a floating casting. Starting wow is reduced to the vanishing point.

BY ALL MEANS, *call your RCA Broadcast Sales Engineer for complete details. Or mail the coupon.*

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AUDIO BROADCAST EQUIPMENT
ɪɪO CORPORATION of AMERICA
:INEERING PRODUCTS DEPARTMENT, CAMDEN, N.J.

In Canada: RCA VICTOR Company Limited, Montreal

RCA Engineering Products,
Department 71L,
Camden, New Jersey

Send me more information (including price and delivery) on your new De Luxe Tape Recorder, Type RT-11A.

NAME____________________

ADDRESS____________________

STATION OR FIRM____________________

CITY____________________ STATE__________

Positions Wanted

(Continued from page 55A)

ANTENNA ENGINEER

B.S. and M.S. in E.E., extra graduate credit. 2 years Navy electronics, 1 year part time teaching, over 2 years aircraft antenna research and development work. Age 27, married. Eta Kappa Nu, Tau Beta Pi, A.I.E.E., I.R.E., Sigma Xi. Desires research and development in VHF, UHF or microwave antennas. Box 483 W.

COMMUNICATIONS ENGINEER

B.E.E. Clarkson College, June 1950. Single, age 26. Formerly A.A.F. radar technician. Metropolitan New York area preferred. Box 484 W.

TELEVISION ENGINEER

Presently employed, 28 months equipment design and advanced development; video, pulse and special associated circuits. Seeking permanent connection with future away from metropolitan New York area. Systems engineering preferred, but will consider research or development. Present salary $5400. Credentials on request. Box 485 W.

ELECTRONIC ENGINEER

M.S.E.E. electronics, University of Illinois 1949. Age 31, married. 4 years A.A.F. radar officer, instructor. 1 year radio manufacturing. Last year and a half in geophysics, still employed. Prefer midwest or southwest. Box 486 W.

ELECTRONIC ENGINEER

B.E.E. 1942. Age 30, married, 1 child. 9 years experience in research and development. Experience includes UHF, micro-

(Continued on page 59A)

Positions Wanted

(Continued from page 58A)

waves and servomechanisms. Interested in changing position. Box 495 W.

ENGINEER

Mature engineer, age 40 broad experience including industrial design, field engineer, foreign experience. B.S. in E.E. University of Illinois, UHF major. Now completing work for M.S. in E.E., physics emphasis in research. Domestic or foreign employment (supervision of overseas branch) will be considered. Box 496 W.

JUNIOR ELECTRONIC ENGINEER

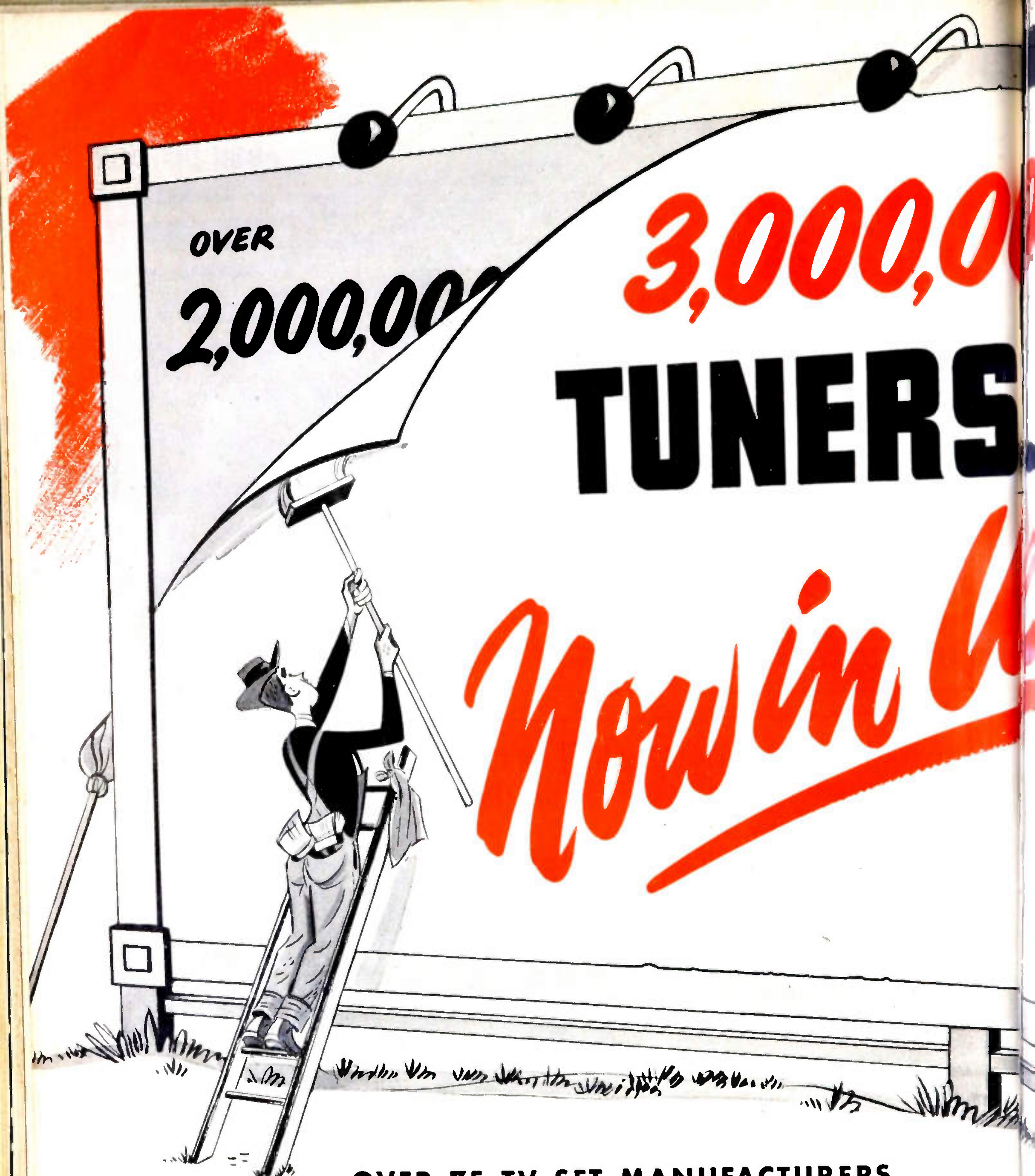
B.E.E. June 1950, C.C.N.Y. Age 25. HAM class B license. Transmitter constructed by myself. Receiver maintenance in Navy. Interested in research or design and development. Resume on request. Box 497 W.

ELECTRONIC ENGINEER

B.E.E. Cooper Union. 4 years experience in radar and Government special apparatus; 1 year in Army radar maintenance; 1 year in television. Age 28, married. Desires position in development work. Box 498 W.

ELECTRICAL ENGINEER

B.S.E.E. Columbia, Tau Beta Pi, Age 31, married. 7 years development, production and administrative experience. Wide shop background, inventive ability, capable trouble shooter. Designed, developed, manufactured electronic controls for machinery, precision electro-mechanical devices. 2½ years Navy, radar and sonar instructor. New York metropolitan area. Box 499 W.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MEMBERSHIP

(Continued from page 49A)

Wisner, R. M., 807 Ninth St., Alamogordo, N. Mex.
Wolff, H. R., 5135 E. North St., Indianapolis 19, Ind.

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Dawes, E. J., 10A Highbury Crescent, London N. 5, England
Herr, R. F., Cloverly Lane, Rydal, Pa.
Jones, R. M., 6733 Jean Ave., Chicago 30, Ill.
Mallach, L. W., 8349 Hatillo Ave., Canoga Park, Calif.
Millis, W. T., 219 Hubert Ct., Owensboro, Ky.
Pawley, M. G., 503 Fontaine St., Alexandria, Va.
Pollack, M., 35 W. 33 St., Chicago 16, Ill.

Transfer to Member

Bush, T. K., 3012 Virginia Ave., Charlotte, N. C.
Carlson, O. E., 25 Riverdale Rd., Pompton Lakes, N. J.
Christman, T. J., 925 Parkman St., Altadena, Calif.
Cooper, J. V. B., 32-44 Bell Blvd., Bayside, N. Y.
Cumming, W. A., Radio & Electrical Engineering Division National Research Council, Ottawa, Ont., Canada
Gundy, P. L., 519 N. Wilson, Royal Oak, Mich.
Harris, A. W., 3348 W. Compton Blvd., Gardena, Calif.
Kush, L. J., Jr., 816 W. Wells St., Milwaukee 3, Wis.
Levy, S. L., 102-15—65 Rd., Forest Hills, L. I., N. Y.
Lawrence, S. C., 1573 E. Forest, Detroit 7, Mich.
Lyle, I. W., Jr., Route 3, Jeffersontown, Ky.
Moore, J. C., Jr., 44 Waverly Pl., Red Bank, N. J.
Moore, W. H., 78-15—19 Dr., Jackson Heights, L. I., N. Y.
Straughn, W. L., Sr., 1254 Euclid St., Beaumont, Tex.
Rowe, H. N., Box E. Sta. E., 1702 Wayne St., Toledo, Ohio
Wybrow, E., 10435 Dunleer Dr., Los Angeles 64, Calif.

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Blodget, R., Holland Rd., Holland, Pa.
Bostwick, W. E., 2615 Sandia Dr., Bel Air, Albuquerque, N. Mex.
Clark, G. F., 207 Mattison Ave., Ambler, Pa.
Doyle, E. M., 2100 Connecticut Ave., N. W., Washington, D. C.
Foodim, C., 122 Richbell Rd., Mamaroneck, N. Y.
Hale, E. M., Box 2180, Rm. 203, Houston 1, Tex.
Leach, J. H., 1778 E. West Highway, Silver Spring, Md.
Lipschitz, S., 7 Beechwold Rd., Saxonwold, Johannesburg, South Africa
Locus, S. S., 3303—43 Pl., Sandia Base Branch, Albuquerque, N. Mex.
Lorentzen, P. E., 5840 Third St., R. D. 1, Verona, Pa.
Martin, D. W., Box 319A, R. D. 1, Newtown, Ohio
Martin, R. E., 621 W. 172 St., New York 32, N. Y.
McBride, G. H., 1707 N. Julian Blvd., Amarillo, Tex.
Nyhen, E. M., 12 Kent Sq., Brookline 46, Mass.
Olson, E. L., 329 S. Wood St., Chicago 12, Ill.
Pierce, C. B., 8223 Kilpatrick Ave., Skokie, Ill.
Reeves, J. M., Information Department, Box 209, Lusaka, Northern Rhodesia
Reiner, M., 19 E. 88 St., New York 28, N. Y.
Rueggeberg, W., Research Laboratories, Armstrong Cork Company, Lancaster, Pa.
Savage, W. B., Wick House, Potterne Wick, Devizes, Wilts., England
Tucker, R. E., 7623 Camellia Ave., N. Hollywood, Calif.

(Continued on page 64A)

MEMBERSHIP

(Continued from page 62A)

Van Arsdell, J. C., Jr., Erie Resistor Corporation, 644 W. 12, Erie, Pa.
Rhiger, R. R., 227 S. E. 52 Ave., Portland 15, Ore.
Schimpf, R. G., 6510 Fairfield Ave., Berwyn, Ill.
Wellinger, R. P., 403 S. Lincoln, Urbana, Ill.
White, W., 251 Ivon Ave., Hamilton, Ont., Canada

The following elections to Associate were approved and are effective as of November 1, 1950:

Algiers, E. P., 6113—26 Ave., Kenosha, Wis.
Anderson, C. M., 1025 Wisconsin Ave., Oak Park, Ill.
Anderson, C. L., 880 Bloomfield Ave., Akron, Ohio
Andrade, L., 30 Ave. D, New York 9, N. Y.
Artificer, A., Station Workshops, Jubbulpore, India
Bauer, J. W., Jr., 309 Acme St., Cheswick, Pa.
Basil, I. T., 3231 Lyndale Ave., Baltimore, Md.
Bazik, W., 22741 Mastik Rd., Cleveland 26, Ohio
Benzuly, H. J., 1140 N. Elmwood Ave., Oak Park, Ill.
Bhote, K. R., 826 S. Wabash Ave., Chicago 5, Ill
Blacketer, J. R., 7636 Carr St., Dallas, Tex.
Bowers, P. E., Armour Research Foundation, 35 W. 33 St., Chicago 16, Ill.
Cartwright, L. W., 3348 Smedley St., Philadelphia, Pa.
Chin, E., 27 Mercer St., Hackensack, N. J.
Corduan, A. E., 6946 Woodley Ave., Van Nuys, Calif.
D'Arcy, E. W., DeVry Corp., 1111 Armitage Ave., Chicago, Ill.
Dellekamp, K. J., Technology Center, Armour Research Foundation, Chicago, Ill.
DeRosa, T. T., 4102 Ave. P, Brooklyn 34, N. Y.
Donaldson, W. G., 80 Lafayette St., New York 13, N. Y.
Drexler, J., 129 Paine Ave., Irvington 11, N. J.
Dunlavey, E. O., 7159 S. Fairfield, Chicago, Ill.
Edelstein, H. N., 1137 Nameoke St., Far Rockaway, L. I., N. Y.
Eggerton, W. H., 27 W. Cuthbert Rd., Collingswood 7, N. J.
Farrance, J., 18913 Parkmount Ave., Cleveland, Ohio
Ferreira, R., CPO-1, U.S.N.T.C., San Diego 33, Calif.
Filips, R, P. 4953 S. Justine St., Chicago, Ill.
French, G. J., 208 Ashland Ave., Pittsburgh 28, Pa.
Gannon, M. J., 607 Hultoñ St., Carnegie, Pa.
Geschwind, R. A., 359 Delmar St., Philadelphia, Pa.
Giesecke, H. W., 500 Alabama Rd., Towson 4, Md.
Goublin, R. O., 3 Ave. Eugenie, St. Cloud, Seine Et Oise, France
Green, R. G., 438 S. Union Dr., Los Angeles 13, Calif.
Gruen, H. E., 12131 S. Princeton, Chicago 28, Ill.
Haas, M. L., Radio & Electronics Parts Corp., 3235 Prospect Ave., Cleveland 15, Ohio
Hainey, C. P., 6215 Vickery, Dallas 14, Tex.
Handelman, S. M., 22 Brevoort Pl., Brooklyn, N. Y.
Herzog, W. F., 120 Steele Ave., Dayton, Ohio
Hood, H. E., 2905 Skyline Blvd., Bakersfield, Calif.
Jennings, T. F., 5052 Sargent Rd., N. E., Washington, D. C.
Joering, E. R., 4316 Crystal Ave., Chicago 51, Ill.
Johnson, E. M., 3 Waite Pl., Troy, N. Y.
Jones, D. M., 38-B Bruan Pl., Richford Village, Clifton, N. J.
Jones, W, T., 2522 Idaho St., Dallas 16, Tex.
Johns, P., 10308 Parkview Ave., Cleveland 4, Ohio
Kaminski, H. S., 4363 N. Kenmore, Chicago, Ill.
Karel, L. G., 6231 S. Stewart Ave., Chicago 21, Ill.
Karp, P. W., 3826—25 St., San Francisco, Calif.
Katella, A. J., 6889 Waldorf Ave., Pennsauken, N. J.
Kern, G. A., 29-B Addison Pl., Clifton, N. J.
Klein, E. F., 528—35 St., Box 78, Los Alamos, N. Mex.
Korman, G., 18 N. Third St., Newark, N. J.
Krug, J. A., 2900—44 St., N. W., Washington 16, D. C.

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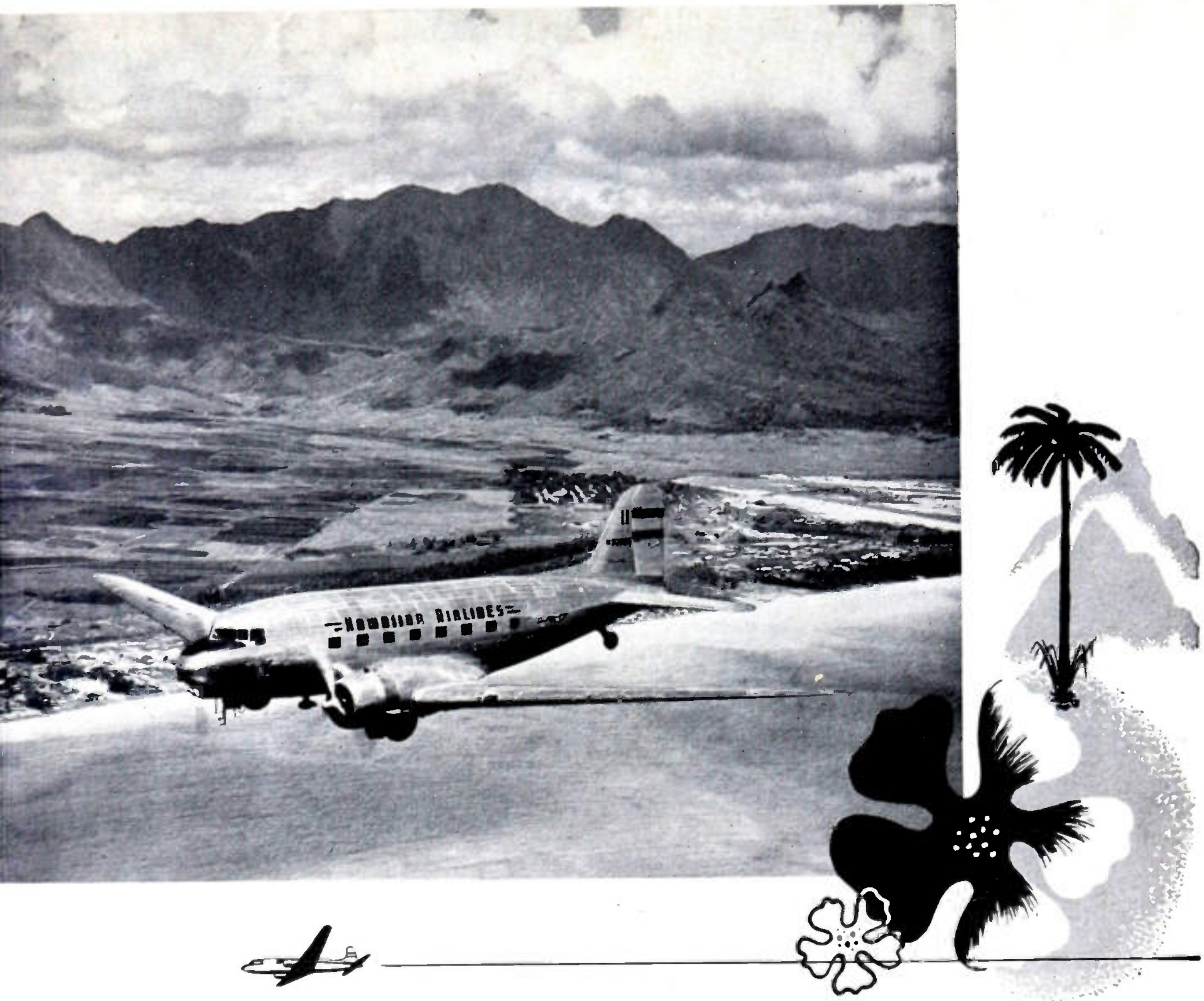


WILCOX ...FIRST CHOICE of HAWAIIAN AIRLINES

VHF AIR-BORNE COMMUNICATIONS

Hawaiian Airlines selected the WILCOX TYPE 361A COMMUNICATIONS SYSTEM for all aircraft. This consists of a 50 watt transmitter, a high sensitivity receiver, and a compact power supply, each contained in a separate ½ ATR chassis. Transmitter and receiver contain frequency selector with provisions for 70 channels . . . ample for both present and future needs.

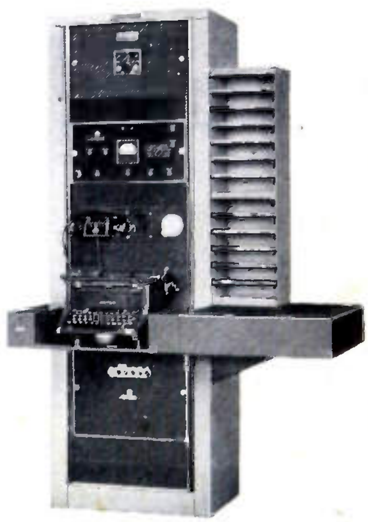
VHF GROUND STATION PACKAGED RADIO

Hawaiian Airlines selected the WILCOX TYPE 428A FACTORY PACKAGED STATION for all ground stations. This consists of the WILCOX 406A fixed frequency 50 watt transmitter, the WILCOX 305A fixed frequency receiver, the WILCOX 407A power supply, the WILCOX 614A VHF antenna, telephone handset, loudspeaker, desk front, typewriter well, and message rack.

DEPENDABLE COMMUNICATIONS FOR THE WORLD'S AIRLINES

During recent months, many of the world's foremost airlines, UNITED, EASTERN, TWA, MID-CONTINENT, BRANIFF, PIONEER, ROBINSON, and WISCONSIN CENTRAL have placed volume orders for similar communications equipment. No greater compliment could be paid to the performance, dependability, and economy of WILCOX equipment than to be **"FIRST CHOICE"** of this distinguished group.

Write Today for complete information on the Type 361A VHF Air-borne Communications System and the Type 428 Packaged VHF Ground Station.



Type 428 Packaged VHF Station

WILCOX ELECTRIC COMPANY

KANSAS CITY 1, MISSOURI, U.S.A.

MEMBERSHIP

(Continued from page 61A)

Kuranuki, L. A., 91 Old Mill Rd., Great Neck, L. I., N. Y.
Kurinsky, J. S., 5133 N. Oak Park Ave., Chicago, Ill.
Lawson, M. H., 12926 Short Ave., Venice, Calif.
Levers, E. O., 45-23—259 St., Great Neck, L. I., N. Y.
Liebersohn, A., 248–252 Hewes St., Brooklyn 11, N. Y.
Lubeck, W. A., 2549 W. Winnemac Ave., Chicago 25, Ill.
Luzer, H. J., 1707 Van Dyke, Detroit 14, Mich.
MacDermott, J. G., 831 Paul St., Gloucester City, N. J.
Maed, A. S., Regharpura Gali 58 House, 4378 Karolbagh, New Delhi, India
Malinowski, S., 5306 W. Foster Ave., Chicago 30, Ill.
Margolis, A. B., 105 E. 106 St., New York, N. Y.
Marsland, H. W., 20 N. Wacker Dr., Chicago, Ill.
Milek, J. T., Hughes Aircraft Company, Culver City, Calif.
Moller, B. N., 623 Hecker, Belleville, Ill.
Morgan, J. F., 2 Parsy Pl., Great Neck, L. I., N. Y.
Morrow, E. E., 9574 Patton Ave., Detroit 23, Mich.
Neff, R. R., 5905 N. Paulina, Chicago, Ill.
Olson, R. E., 21 E. Johnson Ave., Bergenfield, N. J.
Perry, F. E., 12421 First Ave. S., Seattle, Wash.
Petranek, L., 1279 Third Ave., New York 21, N. Y.
Pettus, R., 2319 E. 83 St., Cleveland, Ohio
Polcuch, A. F. G., 9253 Meridian, Seattle, Wash.
Raffel, I., 136 Orient Ave., Jersey City 5, N. J.
Rajan, K. T., Institute of Technology, Trichur, S. India
Read, R. W., 272 Westgate, W., Cambridge 39, Mass.
Rety, E. E., 1607 Belmar Rd., E. Cleveland, Ohio
Richardson, W. R., 303 Broadmoor Rd., Baltimore 12, Md.
Riley, H. E., Port Arthur College, Box 511, Port Arthur, Tex.
Romanyszyn, M. T., 1345 Merriam Ave., New York 52, N. Y.
Rugg, D. A., 1308-A E. Curtis Pl., Milwaukee 2, Wis.
Russell, C. A., 100 S. Edgefield, Dallas, Tex.
Sander, W. E., LaVista Pl., Atlantic, Iowa
Scarborough, D. S., 724 Costa Rica Ave., San Mateo, Calif.
Schultze, W. J., 875 Richmond Ave., Buffalo, N. Y.
Seaton, G., 14314 Ledgewood, Cleveland 11, Ohio
Shannon, G. C., 1640 Belmont Ave., New Hyde Park, N. Y.
Shubel, E. J., 144-08—71 Ave., Flushing, L. I., N. Y.
Slobodin, L., 3211 Quentin Rd., Brooklyn, N. Y.
Smith, R. S., Rt. 2, Box 103, Harrisonburg, Va.
Songayllo, A., Jr., 3255 W. Sunnyside Ave., Chicago, Ill.
Sourek, R. A., 12613 Craven Ave., Cleveland 5, Ohio
Sprague, W. C., 153-C Victoria Dr., Pittsburgh 27, Pa.
Spranger, P. B., 3337 Freer St., Arcadia, Calif.
Steele, S. E., 79 Hamilton St., Berea, Ohio
Trbouich, J., 737 Large Ave., Clairton, Pa.
Treillard, C. E., 7754 Belsrano, Buenos Aires, Argentina
Uhlman, J. C., Box 3, Lac Du Bonnet, Man., Canada
Walters, W. H., 4506½ W. 59 Pl., Los Angeles 43, Calif.
Warzecha, T. D., 1740 N. Wood St., Chicago, Ill.
Welter, L. J., 2395—17 St., Wyandotte, Mich.
White, H. A., 148 Hendrickson Ave., Rockville Centre, N. Y.
Zaruba, E. J., 613 S. Yale Ave., Villa Park, Ill.
Zupansky, M., 5327 N. Winthrop Ave., Chicago 40, Ill.

News New—Products

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

Radiation Detection Meters

A radioactivity-measuring instrument, the Universal Roentgen Meter, is now being produced by **Westinghouse Electric Corp.**, Box 2099, Pittsburgh 30, Pa.

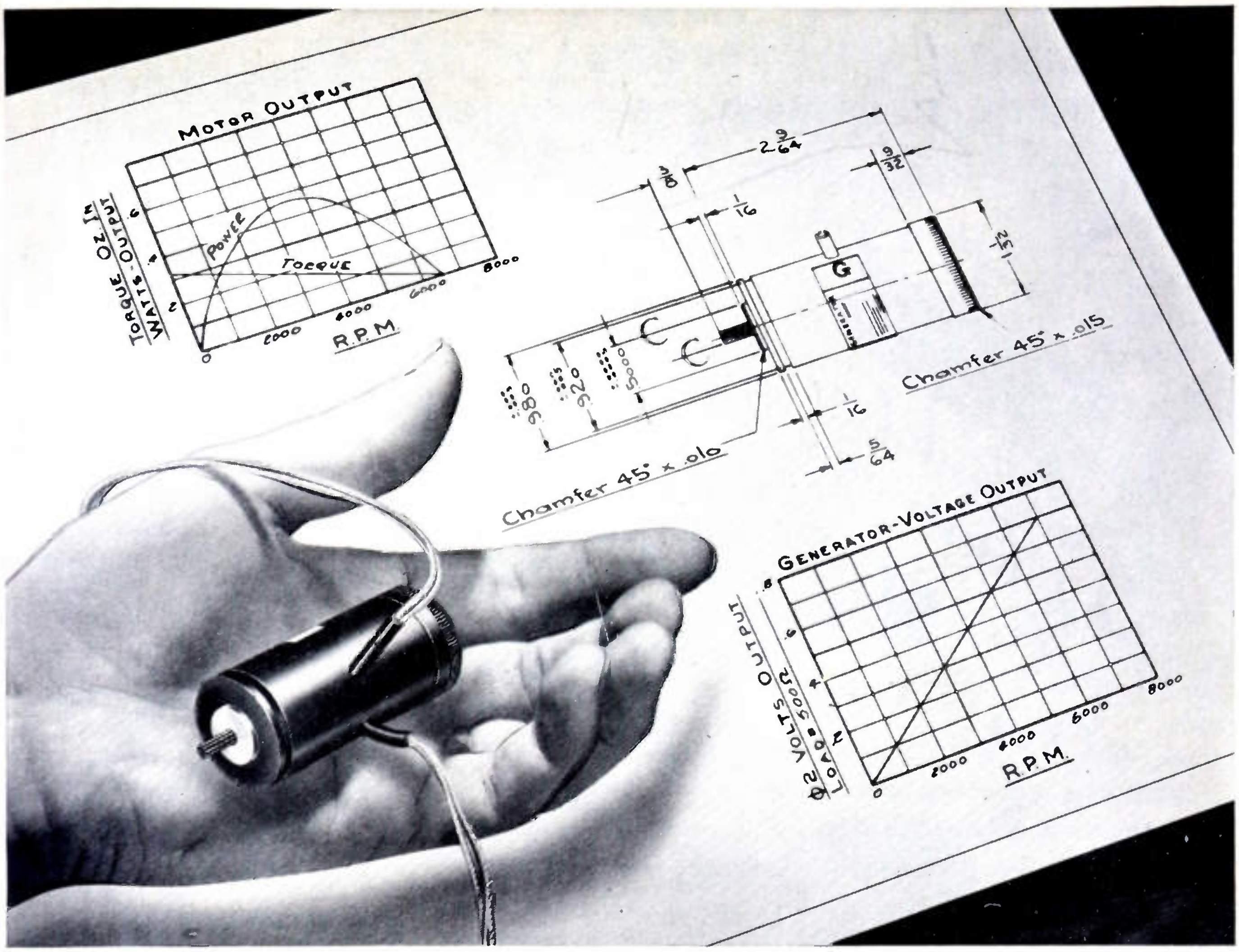
The meter is the measuring part of radiation detection devices which reveals radiation, expressed in milliroentgens, that the device detects, thus indicating the amount of radioactivity present in any area.

The meter is equipped with multiple scales, either four, five or six, which make possible fine readings in all ranges of radiation. The four scale model covers four ranges of radiation: 0 to ½ milliroentgen; 0 to 5 milliroentgens; 0 to 50 milliroentgens; and 0 to 500 milliroentgens.

Setting a switch determines which of the multiple scales will operate and will be visible, thus eliminating incorrect reading by use of the wrong scale.

The instrument is sensitive enough for use in X-ray work, but also accurately measures large amounts of radiation encountered in atomic fission research.

(Continued on page 70A)



Remarkable new compactness in precision control

The extreme compactness of the new Type 1623 Motor-Driven Induction Generator has been achieved with no sacrifice of general performance characteristics. Like its "bigger brothers" in the Kollsman line, the Type 1623 combines, in a single frame, motors of high torque/inertia ratio with generators offering *linear voltage vs. speed* over a wide range.

Where size and weight are prime considerations, this 4.2-ounce unit will prove the solution to many precision control problems. Separate induction motors and generators are also available in the same diameter frame.

For further information on the 1623 and others in the complete Kollsman group of miniature special purpose AC motors—or if you require a unit to your own specifications—write: Kollsman Instrument Division, Square D Company, 80-08 45th Avenue, Elmhurst, N. Y.

Type 1623 Motor-Driven Induction Generator

Motor characteristics: Maximum torque at stall—smooth-running (will not "cog")—fast-reversing—operates from two-phase source, or from single-phase with phase-shifting condenser—available for 60 or 400 cycle operation.

Generator characteristics: Low residual voltage and voltage "spread"—constant frequency output—amplitude directly proportional to speed.

Unit characteristics: Both rotors mounted on same shaft, assuring positive alignment—stainless steel housing—hardened beryllium copper shaft—corrosion-resistant nickel steel laminations—high temperature insulation (up to 200° C. total temperature)—stainless steel precision ball bearings—weight: 4.2 ounces.

KOLLSMAN INSTRUMENT DIVISION

SQUARE D COMPANY

ELMHURST, NEW YORK GLENDALE, CALIFORNIA

News—New Products

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

(Continued from page 68A)

Dual Spotlight Soldering Gun Eliminates Shadows

Dual spotlights to eliminate shadows, and over/under terminals to brace tip and improve visibility are features of the new light-duty soldering gun recently announced by **Weller Electric Corp.**, 821 Packer St., Easton, Pa.

This new model is considerably smaller and lighter than previous, now obsolete, 135-watt guns, and yet has substantially greater soldering capacity.

The gun has dual heat, 100/135 watts, for all light and delicate soldering, 5-second heating to save time and current, trigger-switch control which adjusts heat to the work, and eliminates need of unplugging gun between jobs.

(Continued on page 72A)

Two Bolometer Amplifiers

MODEL 100

- Variable Bandwidth
- Tunable Frequency Range
- Voltage Ratio Expander
- Automatic Normalization
- Self Contained Metering
- Recorder Output

USES

The P & B Bolometer Amplifier Model 100 is a quality amplifier designed for use in connection with making electrical measurements of antennas and associated radio-frequency systems. Standing wave ratios may be quickly determined on either a linear or expanding indicating scale.

The tunable, variable bandwidth, band-pass characteristics of the amplifier make it useful where conditions might render other test equipment useless.

Built to Navy Specifications for research and production testing.

CHARACTERISTICS

Frequency range—400 cycles—5,000 cycles (± 3% calibration accuracy).

Bandwidth—(1/2 voltage) 6, 12, 22, 50, 100 and 300 cycles.

Input Voltage Range
  Signal Channel—10^{-2}—10^{-7} volt.
  Monitor Channel—10^{-2}—10^{-5} volt.
  Expander Operation—10^{-2}—10^{-5} volt.

Input Impedance—250 ohm to 350 ohm.

Meter—logarithmic scale with 100 db decade.

Recorder Output—.01—100 volts @ .01 w. max. (undecaded).

Normalization—output voltage holds within ± ¼db for input changes of ± 5db to both channels.

Bolometer Bias—adjusted in steps of 5% current change over range of 2:1 metered directly.

Voltage Ratio Expander—eighth power expansion.

Power Supply—105/115 volts 50/60 cycles, 175 watts.

Dimensions—19½" high, 17¼" wide, 12" deep.

Weight—65 lbs.

Finish—Blue-grey—Wrinkle.

Ask for Bulletin L-100

MODEL 60

- Self Contained Metering
- Pull Out Meter
- AC and DC Recorder Output
- Panel Selection of 3 Frequencies
- Adjustable and Metered Bolometer Bias

USES

The Model 60 Bolometer Amplifier is a band pass amplifier designed to amplify the output of crystal or bolometer probes used in RF measuring equipment. The amplifier is suitable for all occasions where extremely low audio voltages must be amplified. The recorder output makes the unit particularly useful for antenna pattern recorders requiring either AC or DC input voltages.

DESCRIPTION

The Model 60 Bolometer Amplifier is an audio amplifier incorporating parallel 'T' null networks in a feed back circuit to provide a narrow band pass at any desired frequency within specified limits. The amplifier includes a meter amplifier and an output meter which may be removed from the panel opening for use at remote locations. The recorder output provides a choice of impedances for AC outputs as well as a DC output for those recorders requiring such an input. Input circuits are designed for operation with crystals or 300 ohm bolometers.

CHARACTERISTICS

FREQUENCY RANGE—400 cycles to 5000 cycles (choice of 1, 2, or 3 frequencies within these limits) ±2% frequency tolerance.

BANDWIDTH—(½ voltage points) 8% of bandpass center frequency.

INPUT VOLTAGE RANGE
  Meter—10^{-2}–10^{-7} volt
  Recorder (AC)—10^{-2}–10^{-6} volt

INPUT IMPEDANCE—250 ohm to 350 ohm.

METER—Logarithmic meter scale (0-20 db) with 100 db decade.

RECORDER OUTPUT—AC .01-100 volts @ 50,000 ohms. Additional output impedances of 5000 ohms, 500 ohms, and 250 ohms. DC—0.01-0.75 volts.

BOLOMETER BIAS—Adjustable in steps of 2% current change over a range 2:1—metered directly.

POWER SUPPLY—115 volts 50/60 cycles 40 watts.

DIMENSIONS—19" wide, 8¾" high, 10" deep.

WEIGHT—27 lbs.

FINISH—Blue grey wrinkle panel and mahogany cabinet (unit may be rack mounted without cabinet if desired.)

Ask for Bulletin L-60

PICKARD & BURNS, INC.
240 Highland Avenue — Needham 94, Massachusetts

News—New Products

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

(Continued from page 70A)

Beam-Power Amplifier Tube

A beam-power amplifier tube, designed for use in the audio output stage of television and radio receivers, has been added to the production lines of **Tube Divisions, General Electric Co.,** Syracuse, N. Y.

The new tube, Type 6W6-GT, is capable of delivering relatively large power output and features high sensitivity. When connected as a triode, the tube may be used as a vertical deflection amplifier in television receivers.

Maximum ratings of the tube include: peak positive pulse plate voltage, 1,000 volts; peak negative pulse grid #1 voltage, 200 volts; plate dissipation, 10 watts. The tube has a heater voltage (ac or dc) of 6.3 volts; heater current, 1.2 amperes.

Recent Catalog

• • • A copy of a new soldering gun catalog, fully illustrated, and featuring a new light duty model with dual spotlights is available from **Weller Electric Corp.**, 808 Packer St., Easton, Pa.

(Continued on page 74A)

News—New Products

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

(Continued from page 72A)

Line Voltage Regulators

A new series of line adjusters has been added to the Stancor line of transformers, manufactured by **Standard Transformer Corp.,** 3580 N. Elston Ave., Chicago 18, Ill.

These four units permit operation of electrical devices at 115 volts when the supplied voltage is 65, 75, 90, 100, 115, 130, or 145. They meet power requirements up

(Continued on page 76A)

News—New Products

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

(Continued from page 74A)

to 750 va, 50 to 60 cps. The line adjuster input is correctable in seven steps by means of a selector switch and indicated by an output voltmeter. These units are also useful for altering a 115-volt line above or below that level. They are equipped with a line cord and plug to fit a standard outlet and a plug-in receptacle to accommodate devices to be operated.

Vector Analyzer

A new Vectrolyzer, Type 201, capable of measuring vector relations of alternating voltage from 8 cps to 500 Mc is announced by **Advance Electronics Co.,** P.O. Box 2515, Paterson, N. J.

The frequency range is 8 cps to 10 Mc through panel binding posts, 20 kc to 500 Mc through probe. Input Impedances: probe, 2.5 $\mu\mu f$ shunted by 1/4 megohm and dielectric losses; binding posts, 14 $\mu\mu f$ shunted by 100 megohms and dielectric losses.

The voltage range is 2, 4, 10, 20, and 40 volts, full scale. Phase angle range is 0°–180°, and 180°–360°, ranges with better angular sensitivity can be obtained through panel adjustment. Accuracy is ±3 per cent through panel binding posts, ±1 db through probe for phase angle measurements.

(Continued on page 78A)

for your

Raytheon Tube Requirements

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WORKSHOP

PARABOLIC ANTENNAS

Recent installations of Workshop Parabolic Antennas have replaced hundreds of telephone lines and several coaxial cables. Railroads, oil companies, and broadcast stations report remarkable savings in installation, operation, and maintenance costs.

The Workshop can supply parabolic antennas in a wide range of types, sizes, and focal lengths, plus a complete engineering service.

PARABOLAS — Precision-formed aluminum reflectors.

MOUNTINGS — Various types of aluminum reinforced mountings can be supplied with all antennas.

R. F. COMPONENTS — Precision machined and heavily silver plated. Critical elements protected by low-loss plastic radome.

PATTERN and IMPEDANCE DATA — A series of elaborate measurements of both pattern and impedance are made to adjust the settings for optimum performance.

POLARIZATION — Either vertical or horizontal polarization can be obtained easily by a simple adjustment at the rear of the reflector.

ENGINEERING and CONTRACT SERVICE — If your product or service requires high-frequency antennas, get in touch with the WORKSHOP. As the pioneer and acknowledged leader in this field, we can help you. Be it research, design, test, or production, our highly-skilled staff, backed by the finest laboratory equipment in the industry, can solve your antenna problem with a minimum of time and expense. Write, or phone Needham 3-0005. No obligation.

OTHER WORKSHOP ANTENNAS

Aeronautical Ground Station
For aircraft communications — omnidirectional.

Directional and Bi-Directional
For police, highway patrol, railway, forestry, utilities, oil fields.

Beacon
For fire, police, taxicab, and private fleet communications.

TV, FM and Amateur

The WORKSHOP ASSOCIATES, Inc.

Specialists in High Frequency Antennas

135 Crescent Road, Needham Heights 94, Massachusetts

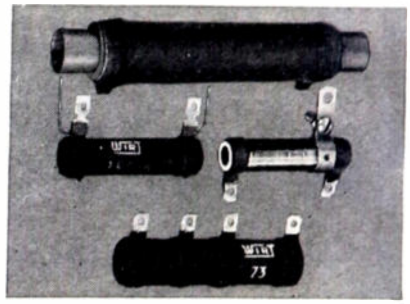
News—New Products

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

(Continued from page 76A)

Improved Organic Coating for Resistors

An improved and thoroughly tested organic cement coating, trade named "Phenocote," materially adds to the shelf and service life of the line of resistors produced by **Wirt Co.,** 5221-27 Greene St., (Germantown) Philadelphia 44, Pa., manufacturers of components for the radio, electrical and electronic industries.



The new coating, when applied to resistor wire which is space wound on low-loss ceramic tubes, produces high stability for the resistance winding, and offers maximum protection against moisture.

(Continued on page 80A)

News—New Products

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

(Continued from page 78A)

humidity, and electrolysis. Inert chemically, it will not affect the most delicate windings; however, it is recommended for both fine and larger wire sizes. The improved coating may be applied to fixed-variable, ferrule, and Edison base styles of resistors.

Intermodulation Meter

Measurements Corp., Intervale Rd., Boonton, N. J., announces the development of a completely self-contained intermodulation meter.

This new laboratory standard, Model 31, consists of two principal sections, a test signal generator and an analyzer. The generator section produces two sinusoidal voltages, one of low frequency and the other a high frequency, which are mixed in a 4/1 voltage ratio and applied to the apparatus under test.

The signal is then received by the analyzer section, where it is filtered, amplified, demodulated, and metered. The meter is direct-reading in percentage of intermodulation and input volts.

This instrument is useful for evaluating the performance of audio systems, for the adjustment and maintenance of AM and FM receivers and transmitters; for checking linearity of film and disk recordings and reproductions, for checking phonograph pickups and recording styli, for adjusting bias in tape recordings, for quality control of all audio components and equipment, and for many other applications.

Bolometer Bridge

The General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass., recently developed the Type 1651-A bolometer

bridge for maximum flexibility in application, so that it can be adapted to a variety

(Continued on page 81A)

News—New Products

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

(Continued from page 80A)

of power measurement problems. It can be used, not only with **General Radio** bolometers, but also with those of other manufacture having resistances between 25 and 400 ohms. Measurements can be made either by a direct-reading or a substitution method. Current range is 0 to 100 ma; power range is 0 to 500 milliwatts.

Matching transformers and other accessory equipment can be assembled from General Radio Type 874 coaxial elements.

Plant Expansion

The General Electric Co., Schenectady, N. Y., has announced that it will reopen its Clyde, N. Y., plant and transfer the production of germanium products now made at the GE, Thompson Rd. plant in Syracuse to the Clyde factory.

W. R. G. Baker, company vice-president and general manager of the GE Electronics Dept., said the transfer is being made because of expanded production requirements for these products, and also to make room for increasing government business at the Syracuse plants.

(Continued on page 82A)

How Technical Books Are Bought

By Harry C. Waterston

Mr. Waterston is president of Waterston & Fried, Inc., an advertising firm which handles such accounts as Wiley, Reinhold, and Cornell Maritime press, technical and trade journal publishers.

Have you ever thought about the book buying habits of the scientist or technician? Does he generally buy his books from a bookstore or through an advertisement in a professional journal? Is he influenced more by book reviews than by personal recommendations in his selection of books?

The factors that influence book buying in the technical and scientific fields have been of great interest to us. Often we have asked technically-trained friends and acquaintances how and where they bought books. We have checked with publishers whose accounts we handled, for their experiences and opinions. However, we found many divergent theories among publishers as to how technical books are bought.

Our interest in this subject stems from the fact that for almost a decade we have been preparing advertising for books written for special audiences. Chemistry, music, business, medicine, aeronautics, art, radio electronics and many other subjects are included in the list of titles we have promoted.

Recently, we were discussing with William Copp, advertising manager of the PROCEEDINGS OF I.R.E., the need for factual information on what influenced people to buy technical books. We both agreed that a survey should be made to secure this important information.

Mr. Copp told us that he and the Institute of Radio Engineers would be glad to finance such a survey, and he suggested that our company conduct it. We were delighted to offer our name and facilities to such a worthwhile cause.

We decided to select 1,000 readers of the PROCEEDINGS OF I.R.E. From the list of subscribers we chose the first forty names of each letter of the alphabet. *(Continued at Right)*

News—New Products

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

(Continued from left)

HOW TECHNICAL BOOKS ARE BOUGHT

The questionnaire was mailed on our firm's letterhead. In introducing the subject, we said, "One of our mutual friends in radio and electronics has asked us to obtain some information on the book interests and buying habits of leading radio engineers."

Of the 1,000 questionnaires mailed, 17 were returned undelivered, 290 subscribers, or 29% of the balance, returned the form with the answers filled in. Replies came from Canada, Colombia, France, Israel, Venezuela, Cuba, India, Sweden and Hawaii, as well as from all parts of the United States.

The first question was, "*Approximately how many technical and scientific books do you buy in a year?*" Several replied that they bought as many as 40 to 50 books. One said that he bought $100 worth, but the average was more modest. Here is the tally:

1 to 5 books	59%
6 to 10 books	29%
More than 10 books	12%

"*What is your usual method of purchasing these books?*" was the next question. Here we listed four choices and an "*Other*" for those who purchase their books in an unusual manner.

Buy books from bookstores	52%
Through purchasing agent or other person in own organization	28%
Clip coupon from ads	9%
Write or phone publisher	47%
Other: School and engineering societies, distributors of radio parts, desk copies, etc.	3%

Many checked more than one method of purchasing books.

"*What guides you in the selection of technical books?*" Four choices and an "*Other*" were listed here.

Due to a clerical error, "publisher's literature" was omitted from the questionnaire. However, the opportunity for a "write-in" vote was available to any subscriber under "*Other*" guides to selection. Fortunately, every book publisher has exact figures on the selling ability of direct mail literature. Notwithstanding this omission, we believe the statements made by those participating in this survey still give us a clear picture as to what influences them in the selection of technical titles.

Personal recommendation by associates in the field	64%
Book reviews in technical magazines	66%
Recommendation of book salesman	2%
Advertisements for books in technical magazines	37%

(Continued on page 84A)

News—New Products

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

(Continued from page 82A)

Publisher's literature . . . . (Written in under "*Other*." See preceding paragraph.)	15%
Other (Personal perusal, library, bookstore, publisher's showroom, borrow book, knowledge of author . . .	15%

Here, too, more than one classification was checked by most participants.

It is interesting to note that, while 52% purchase books from bookstores, only 2% say they are influenced by the recommendations of a book salesman. It is obvious, therefore, that the technical book buyer must be sold on a book—its subject matter, its advantages to him in his field, the name and authority of the author, and its publisher—*before* he walks into a bookstore.

Another interesting point is that while 37% admit that they are influenced by book advertisements in technical publications, only one-fourth of these actually clip coupons from ads to purchase books.

We also thought it would be a good idea for technical people to express their preference for book publishers in their field. This question was asked:

"*What book publishers do you consider publish the best books in your field?*" No check-list was supplied here. Each person wrote the names of the publishers he thought best. A total of thirty-seven publishers was named. The leaders were:

McGraw-Hill	84%
John Wiley & Sons	61%
Van Nostrand	30%
Dover	6%
Prentice-Hall	5%
Macmillan	5%
Cambridge University	3%
Oxford University	2%

No questionnaire is complete without some space for "*Special Remarks*." So we provided space for free expression for those who were good enough to take the trouble to fill out the form. The following are a typical "cross-section" of the comments we received.

A Canadian commented:

"Textbooks are very expensive in Britain. American books are prohibitive now on devalued Sterling."

A Cambridge, Mass. subscriber offered this suggestion:

"Eliminate elementary review material from many books and thereby reduce the price, which is generally too high."

A Brooklyn, N. Y. member observed:

"Most books in the field tend to start with too few assumptions about the knowledge of the reader. Elementary material should be confined to strictly elementary texts. This is a policy that all publishers should follow more consistently than they do."

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News—New Products

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

(Continued from page 84A)

From Buffalo, N. Y. (after mentioning the three leaders):

"Other technical publishers are apparently too proud to push their wares."

From Dallas, Texas:

"Would undoubtedly buy more technical books were it possible to 'look them over' locally . . . publishers are selling their market short—scientific men must be by nature and necessity eager for books, and reduced prices should reap a large increase in sales volume."

A Naval Commander in Portsmouth, Va.:

"Electronics books should be published in cheaper (possibly paper) editions. Considering their high rate of obsolescence they cost too darn much!"

East Chicago, Ill. contributed:

"A book prepared by a single author of outstanding reputation in his field is superior to one produced through a collaboration of many authors."

From Old Saybrook, Conn.,

"Would like to see more books on the Philosophy and Nature of Scientific Theory to arouse interest in fundamental research in this country."

A Challenge from Pasadena, Cal.:

"There ought to be a more effective way of bringing books to the attention of scientific people than methods now in use."

This St. Paul, Minn. subscriber was very critical:

"I find that manufacturers' data is generally as complete and cheaper—too many books carry the same material."

A Cynic from Pittsburgh, Pa. cried:

"What best books? Most are revisions of revisions."

An Advertising-conscious New Yorker wrote:

"Advertisements undoubtedly have an unconscious effect in my purchases of technical literature."

Improved Flexible Electrical Conduit

An improved flexible electrical conduit has been devised by Elliott Solero, of **National Electric Products, Corp.,** P.O. Box 897, Pittsburgh 30, Pa.

The conduit consists of an inner woven tubing made of longitudinal *Fiberglas* yarns, and a spiral wrapping of metal foil, with an outer braided jacket of aluminum wire. Conventional construction makes use of a spiral armor of interlocked aluminum strip over a braided aluminum wire jacket.

Using less metal than the conventional type, the new conduit is lighter, has greater flexibility, affords more uniform shielding and provides better resistance to damage from moisture, flame, oil spray and fungus.

The new flexible conduit is expected to find wide usage in applications involving high-frequency currents—notably in aircraft radar equipment, automotive radio insulation, etc.

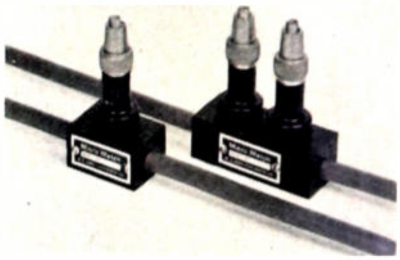
(Continued on page 86A)

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

(Continued from page 85A)

New Small Coupler

A new Micromatch, Model 570, series designed as a transmitter component to continually monitor rf power output, vswr, and sidetone is being produced by **M. C. Jones Electronics Co.,** 96 Main St., Bristol, Conn.



Model 570 has a frequency range of 20 to 2,000 Mc., and an impedance of 51 ohms. It is supplied with RG-9/uc cable, or female N type connector which accepts UG-21/U connector attached to RG-9/U cable.

Meter scale reads 0 to infinity: A vswr of 3.0 corresponds to approximately half scale deflection.

Audio frequency output available for monitoring when used with an AM transmitter.

(Continued on page 87A)

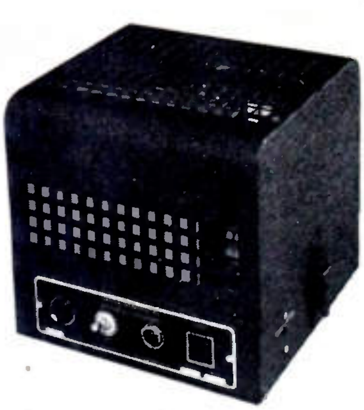
News—New Products

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

(Continued from page 86A)

Frequency Standard

The new Type 2005, frequency standard, with an output frequency of 60 cps accurate to 1 part in 100,000 in temperature range from 0 to 60° C, has been designed by **American Time Products, Inc.,** 580 Fifth Ave., New York 19, N. Y.



Output power is 10 watts, 115 volts approximate sine wave. The input is 115 volts, 50 to 400 cps 45 watts.

(Continued on page 88A)

News—New Products

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

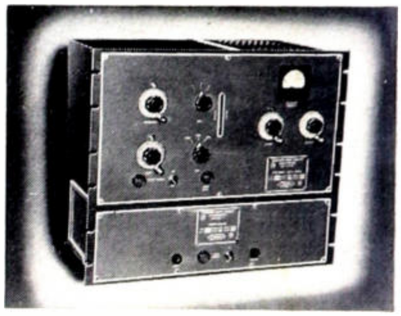
(*Continued from page 87A*)

This is a compact source of accurate frequency at a commonly needed power level. It is useful in running small motors, timers, and clocks. It is also useful in making frequency measurements, providing timing marks in oscillographs and high-speed cameras.

The source of the accuracy is a type 2001-2 240 cps tuning fork standard incorporated in the unit.

Frequency Shift Keyer

To meet more stringent requirements, **Northern Radio Co., Inc.,** 143 W. 22 St., New York 11, N. Y., has designed and produced the new Type 105 Model 4, frequency shift keyer.



(*Continued on page 89A*)

News—New Products

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

(Continued from page 88A)

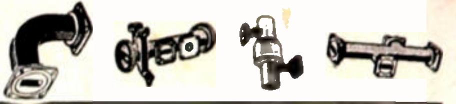
This exciter replaces the crystal oscillator in a transmitter and produces mark and space carrier shift for transmission of teleprinter or telegraph signals. It is composed of 6 main sections: keying circuit, reactance tube, shifted oscillator, crystal oscillator, modulator and power amplifier. Passing through the keying stage, a keying signal is limited in amplitude, then fed to the balanced reactance tube oscillator where it varies the frequency according to applied intelligence. This shifted frequency is heterodyned with the output from the crystal oscillator in the modulator stage, and the sum frequency drives the power amplifier.

Outstanding feature of the Type 105 Model 4 is the highly stable crystal oven which has a temperature control of ±0.1° C at 60°, with heaters on 4 sides of the inner oven.

Other features of this unit are direct reading frequency calibration of: shift from 0 to 1,000 cps; mixer and output tuning dials from 2.5 to 6.7 Mc; output frequency vernier ±600 cps.

(Continued on page 91A)

MICROWAVE



PULSE TRANSFORMERS

G.E.K.-2745 ....$39.50
G.E.K.-2744-A. 11.5 KV High Voltage, 3.2 KV Low Voltage @ 200 KW oper. (270 KW max.) 1 microsec. or ¼ microsec. @ 600 PPS $39.50
W.E. $166173 Hi-Volt input transformer. W.E. Impedance ratio 50 ohms to 900 ohms. Freq. range: 10 kc. to 2 mc. 2 sections parallel connected, potted in oil $36.00
W.E. KS 9800 Input transformer. Winding ratio between terminals 3-5 and 1.2 is 1.1:1, and between terminals 6-7 and 1.2 is 2:1 Frequency range: 380-520 c.p.s. Permalloy core $6.00
G.E. $K2731 Repetition Rate: 635 PPS. Pri. Imp: Ohms. Sec. Imp: 450 Ohms Pulse Width: 1 Microsec. Pri. Input: 9:5 KV PK Sec. Output: 28 KV PK. Peak Output: 800 KW Bifilar 2.75 Amp. $64.50
W.E. $D169271 Hi Volt input pulse Transformer $27.50
G.E. K2450A. Will receive 13KV. 4 micro-second pulse on pri. secondary delivers 14KV Peak power out 100 KW G.E...$34.50
G.E. $K2748A. Pulse input line to magnetron $36.00
$9262 Utah Pulse or Blocking Oscillator XFMR Freq. limits 790-810 cy-3 winding turns ratio 1:1:1 Dimensions 1 13/16 x 1¼" 19/32 ....$1.50
Pulse 131-AWP L-421435 ...$6.00
Pulse 134-BW-2F L-440895..$2.25
RAY-WX-4298F $93.50
GE-K6824730 ....$50.00
GE-K9216945 ....$50.00
$7766489—9332
A 7766490—
UX 7350 ....$6.95
$0350(218961) $2.03
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AVAILABLE IN STOCK 9318
9280 WRITE

ARMY-NAVY TEST SETS

LU-1 Freq. Meter and Test Oscillator. Type CRV-TVN-9HU Power Supply. M.I.T. Rad. Lab.
TVN-8SE Klystron Power Supply. M.I.T. Rad. Lab.
CS60ABW Watt Meter—Wavemeter. 3 centimeter.
APR5 Receiver—1000 to 6000 mcs.
AN/CPN-8—10 centimeter 40 kw. output RF package. Includes magnetron oscillator, complete modulator, complete receiver, complete signal and power analyzer with 5" scope. 115V AC input.
Dehydrator Unit CPD 10137 Automatic cycling.
Compressor to 50 lbs. Compl. for Radar XSMN. Line New $425.00
SO-3 Receiver. 30 mc. IF. 6 stages 6AC7. 10 MC. Band width inpt. 5.1 mo B.W. per stg. 9.6 volt gain per stage as desc. in ch. 13 vol. 23 M.I.T. Rad. Lab. Series $99.50
TS12 3 cm Slotted Line
TS13 3 cm Signal Generator
TS33 3 cm Frequency Meter
TS35 3 cm Signal Generator
TS36 3 cm Power Meter
TS45/AMP3 3 cm Signal Generator
TS62 3 cm Echo Box
TS102
TS108 Dummy Load
I—185A oscillator
I—158 Range Calibrator
I—233 Range Calibrator
BC 438 Freq Meter
RF—Preamp
GR—Capacity bridge $216
GR—Uni Galvo Shunt $229
GR—1000 Avd Osc $213
TS 226A/AP Power Meter 0 1000W
Sig Gen $804 8-330 MC
BC 221 Freq Meter
TS 10/AP
TS 69/AP Freq Meter
I-114 Test Set

VARISTORS

D-170225 ....$1.50
D-167176 ....$1.50
D-168687 ....$1.50
D-171812 ....$1.50
D-171528 ....$1.50
D-168442 ....$3.00
D-165593 ....$1.25
D-98836 ....$2.00
D-161871A $2.85
D-171121 ....$1.50
D-162356(306A) $1.50
D-163357 ....$2.00
D-99946 ....$2.95

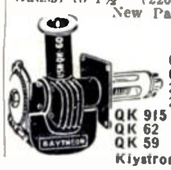
THERMISTORS

D-167332 (tube) $1.50
D-170396 (bead) $1.50
D-167613 (button) $1.50
D-164699 for MTG in "X" band Guide $2.50
D-167018 (tube) $1.50

MAGNETRON MAGNETS

Gauss	Pole Diam.	Spacing	Price
4850	¾ in.	⅝ in.	$12.50
5200	11/32 in.	1 5/16 in.	$17.50
1300	1⅝ in.	1 5/16 in.	$12.50
1860	1⅝ in.	1½ in.	$14.50

Electromagnets for magnetrons ....$24.50 ea.
GE Magnets type M7765115, GI Distance Between pole faces variable. 2 1/16" (1900 Gauss) to 1½" (2200 Gauss) Pole Dia. 1⅝" New Part of SCR 584 ......$34.50



MAGNETRONS

QK 61	2J32	2J61	720CY	
QK 60	2J37	2J62	725-A	
2J21	2J38	3J31	730-A	
2J22	2J39	5J30	728	
QK 915	2J26	2J40	714AY	706
QK 62	2J27	2J49	718DY	700
QK 59	2J31	2J34	720BY	

Klystrons 723A, 707B, 417A, 2K41

RADIO SYSTEMS

White Radio Telephone Model $WRM55—ship to ship—shore to ship—small airports—mines—plantations — inter island — ranches. 10 channel fix tuned rec. & Xmitter. Xmitter. pwr. output in excess of 100W unmodulated into antenna of 18 & 100 MMF. Freq. Range 2-12 MC. Can be modified to increase range. Xtal controlled. 110V 60 cy or 220V 60 or 25 cy. Meas. 24" H x 19" W x 14" D. 125 lbs. Write or phone for data.
TAJ 500 Watt Low Frequency Transmitter 150-550KC CW-MCW.
TBK 500 Watt High Frequency Transmitter 2-18 MC. A1. A2. A3. Emission Mfg. by RCA.

THE MUST OF THE MONTH

Complete 3 CM Radar System Equipment

40 KW peak transmitter, pulse modulator, receiver, using 723AB, power supply operating from 115V 800 Cycle, antenna system. Complete radar set neatly packaged in less than 16 cubic feet, all tubes. In used but excellent condition—$350.00. This price for laboratories, schools, and experimental purposes only.

High Voltage Power Supply

15 KV at 30 Ma DC, Bridge Rectifier $125.00

MICROWAVE ANTENNAS

RELAY SYSTEM PARABOLIC REFLECTORS: approx. range: 2000 to 6000 mc. Dimensions: 4' x 3' rectangle, now $35.00
TDY "JAM" RADAR ROTATING ANTENNA. 10 cm. 30 deg. beam. 115 v.a.c. drive. New $100.00
SC-13 ANTENNA 24" dish with feed-back dipole 360 deg. rotation, complete with drive motor and selsyn. New $128.00
Used $45.00
DBM ANTENNA. Dual, back-to-back parabolas with dipols. Freq. coverage 1,000-4,500 mc. No drive mechanism $65.00
AS125/APR. Cone type receiving antenna. 1080 to 3208 megacycles. New $4.50
140-600 MC CONE type antenna, complete with 25' sectional steel mast, guys, cables, carrying case, etc. New $49.50
ASD 3 cm. antenna, used, ex. cond. $49.50
YAGI ANTENNA AS-46A, APG-4, 5 elements ....$14.50 ea.
DISH FOR PARABOLA 30" $4.85
AN 122 ....$22.50
RC 224 ....$99.50
AS 17/APS
DAK Directional Finder Loops
Adcock Arrays
SA-1 Radar
200 MC. Bed Spring
LP21-A Airborne Dir. Find. Loop r/ Selsyn & Loop Housing
APS 4 Ant.
AN 128A 200 MC. Array
Write for Info and Price

RADAR SYSTEMS AND COMPONENTS IN STOCK

APS-2 10 CM AIRBORNE
APS-3 3 CM AIRBORNE
APS-4 3 CM AIRBORNE
APS-6 3 CM AIRBORNE
APS-6A 3 CM AIRBORNE
APS-10 3 CM AIRBORNE
APQ-13 3 CM AIRBORNE
APS-15 3 CM AIRBORNE
APS-31 3 CM AIRBORNE
CPN-8 10 CM GROUND BEACON
CEXH 10 CM GROUND BEACON
FD-MARK 4 600 MC SHIP GUNLAYING
MARK-10 10 CM SHIP GUNLAYING
SA 200 MC SHIP AIR SEARCH
SC 200 MC SHIP AIR SEARCH
SD 200 MC SUBMARINE
SE 10 CM SURFACE SEARCH
SF 10 CM SURFACE SEARCH
SG 10 CM SURFACE SEARCH
SJ 10 CM SUBMARINE
SK 200 MC AIR SEARCH
SL 10 CM SURFACE SEARCH
SN 10 CM PORTABLE
SO (ALL SERIES) 10 CM SURFACE SEARCH
SQ 10 CM PORTABLE
SW 200 MC PORTABLE
SCR 518 400 MC ALTIMETER
SCR 520 10 CM AIRBORNE
SCR 533 200 MC AIR SEARCH
SCR 545 10 CM TRACKING 800 MC SEARCH
SCR 663 SEARCHLIGHT TRACK

SONAR SYSTEMS AND COMPONENTS IN STOCK

QBF
QBG
QC
QCJ
QCL
QCD
QCS
QCU
WEA

3000 MC BENCH TEST PLUMBING

TEST EQUIPMENT

10 CM Wavemeter WE type B435490 Transmission type, Type N Fittings, Veeder Root Micrometer dial., Gold Plated W/Calib. Chart P/o Freq. Meter X66404A. New $99.50
AS14A/AP-10 CM Pick up Dipole with "N" Cables $4.50
LHTR. LIGHTHOUSE ASSEMBLY. Part of RT-39 APG 5 & APG 15. Receiver and Trans Cavities w/assoc. Tr. Cavity and Type N CPLG. To Revr. Uses 2C40, 2C43, 1B27. Tunable APX 2400-2700 MCS. Silver Plated $49.50
Beacon Lighthouse cavity 10 cm with miniature 28 volt DC FM motor. Mfg. Bernard Rice ....$47.50 ea.
Magnetron to Waveguide Coupler with 721A Duplexer Cavity, gold-plated $45.00
721A TR Box complete with tube and tuning plungers $12.50
McNally Klystron Cavities for 707B or 2K28. Three types available $4.00
F-29/SPR-2 Filters. Type "N". input and output $12.50
726 Klystron Mnt Tunable output, to type "N" complete, with socket & Mtg. bracket ...$12.50
WAVEGUIDE TO ⅞" RIGID COAX "DOORKNOB" ADAPTER. CHOKE FLANGE, SILVER PLATED BROAD BAND $32.50
WAVEGUIDE DIRECTIONAL COUPLER, 27 db. Navy type CABV-47AAN, with 4 in. slotted section $32.50
SQ. FLANGE to rd choke adapter. 18 in. long OA 1½ in. x 3 in. guide, type "N" output and sampling probe $27.50
AN/APR5A 10 cm antenna equipment consisting of two 10 cm waveguide sections, each polarized, 45 degrees ..$75.00 per set
POWER SPLITTER: 726 Klystron input dual "N" output ..$5.00

⅞" RIGID COAX

10 CM FEEDBACK DIPOLE ANTENNA, in lucite ball, for use with parabola ⅞" Rigid Coax Input $8.00
721A TR cavities, heavy silver plated ....$2.00 ea.
Magnetron Coupling with TR Loop. $7.50
Sperry Rotating Bend, pressurized $22.50
5 Ft. Lengths Stub Supported, gold-plated, per length ..$7.50
Short Right Angle Bends (for above) $2.50

4000 to 6000 mcs. Bench Test Plumbing 2" x 1" WAVEGUIDE

SLOTTED LINE. DeMornay type 332 complete with probe, etc. $600.00
FLAP ATTENUATOR $48.00
VARIABLE STUB TUNER AND LOW POWER TERMINATION $48.00
WAVEMETER TEE $48.00
ADAPTERS:
Choke to choke $18.00
Cover to cover $14.00
Choke to cover $16.00
WAVEGUIDE TO TYPE "N" ADAPTER $45.00
DIRECTIONAL COUPLER. Two hole type, type "N" output $48.00
KLYSTRON MOUNT. Equipped with tunable termination and micrometer adjust, klystron antenna tuning $110.00
CRYSTAL MOUNT. Equipped with tunable termination and micrometer adjust crystal tuning $125.00
TUNABLE TERMINATION. Precision adjust $90.00

6000 Mc. to 8500 Mc. Bench Test Plumbing

1½" x ¾" WAVEGUIDE

KLYSTRON MOUNT. DB356 complete with shield and tunable termination $125.00
FLAP ATTENUATOR. DB361 ....$45.00
VARIABLE STUB TUNER $90.00
WAVEGUIDE TO TYPE "N" ADAPTER $18.50
WAVEMETER TEE. DB352 ....$32.50
MAGIC TEE $80.00
DIRECTIONAL COUPLER. Two hole 25DB coupling, type "N" output $25.00
PRECISION CRYSTAL MOUNT. Equipped with tuning slugs and tunable termination $125.00
TUNABLE TERMINATION. Precision adjust $70.00
LOW POWER LOAD $35.00

8500 Mc. to 9600 Mc. Bench Test Plumbing 1" x 1½" WAVEGUIDE

KLYSTRON MOUNT. DeMornay Budd type DB380 for 2K25, etc., includes tunable termination $70.00
VARIABLE STUB TUNER. DB536, 180 degree phase shifting capacity $70.00
FLAP ATTENUATOR. DB385. Maximum Attenuation 10DB $25.00
Waveguide to "N" Adapter DB377 ....$15.00
LOW POWER TERMINATION. DB381 ....$18.50
UNI-DIRECTIONAL COUPLER. DB390. 23DB type "N" output $18.50
PICK UP HORN. Type "N" output $4.50
WAVEMETER. 8500 to 9400 mcs. with calibration. Micrometer adjust head. Reaction type $85.00
WAVEGUIDE LENGTHS. Plated and fitted with couplings available in 6", 12", 24", 30", 60" sections ....$2.00 per ft.
90 DEGREE ELBOWS. E or H plane. 2½" radius $12.50
MITERED ELBOWS. E plane $10.00
90 DEGREE TWIST. 6" long $8.00
BULKHEAD FEED—THRU ASSEMBLY $15.00
PRESSURE GAUGE SECTION. 15 lb. gauge and press. nipple $10.00
PRESSURE GAUGE. 15 lbs. $2.50
DUAL OSCILLATOR-BEACON MOUNT. P/O APS10 Radar for mounting two 723A/B klystrons with crystal mts. matching slugs, shields $42.50
DUAL OSCILLATOR MOUNTS. (Back to back) with crystal mount, tunable termination, attentuating slugs $18.50
Directional Coupler, UG-40/U Take off 20 DB $17.50
Directional coupler, APS-6 type "N" take off 20 DB calibrated $17.50
Rotary Joint Choke to Choke $10.00
2K25/723 AB Receiver local oscillator Klystron Mount, complete with crystal mount, Iris coupling and choke coupling to TR $22.50
TR-ATR Duplexer section for above $8.50

1¼" x ⅝" WAVEGUIDE

TUNABLE TERMINATION. Precision adjust $65.00
LOW POWER TERMINATION $25.00
MAGIC TEE $45.00
OSCILLATOR MOUNT. for four 723AB klystron $38.50
90 DEGREE ELBOWS. E or H plane $12.50
WAVEGUIDE LENGTHS. Cut to size and supplied with 1 choke, 1 cover, per length $2.00 per ft.
WAVEMETER: Absorption type. Precision micrometer adjust. Very high Q $150.00

23,000 TO 27,000 MC. BENCH TEST PLUMBING ½" x ¼" WAVEGUIDE

PRECISION SLOTTED LINE. Adjustable probe $200.00
DIRECTIONAL COUPLER Wave meter Mount, 12DB $60.00
PRECISION VARIABLE ATTENUATOR, mfg. Bernard Rice $90.00
LOW POWER LOAD $20.00
SHUNT TEE $35.00
WAVEGUIDE LENGTHS. 2" to 6" long, goldplated with circular flanges and coupling nuts ....$2.25 per inch
APS-34 Rotating Joint $49.50
Right Angle Bend E or H Plane. specify combination of couplings desired $12.00
45° Bend E or H Plane, Choke to cover $12.00
Directional coupler CU-103/APS32 ....$49.50
Mit. Elbow, cov. to cov. ... $4.00
TR-ATR Sect. choke to cov. $4.00
Flex. Sec. 1" choke to choke $5.00
"S" Curve Choke to Cover .$4.50
Adaptor, rnd. to sq. cov. ..$5.00
Feedback to Parabola Horn with pressurized window $27.50
Low Power Load, less cards $18.50
K Band Mixer Block $45.00
Waveguide ½ x ¼" $1.00 per ft.
90° Twist $10.00
"K" Band Directional Coupler CU104/APS-34 20 DB $49.50 ea.
3J31 Magnetrons $55.00

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News—New Products

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

(Continued from page 89A)

Television Marker Generator

A new television marker generator, Type 501, designed particularly for use with TV sweep signal generators, has been announced by the **Radio Tube Div., Sylvania Electric Products Inc.**, 1740 Broadway, New York 19, N. Y.

Crystal-controlled signals are provided by an entirely separate self-contained crystal oscillator which may be operated at any frequency, fixed by a plug-in crystal with-

(Continued on page 93A)

News—New Products

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

(Continued from page 91A)

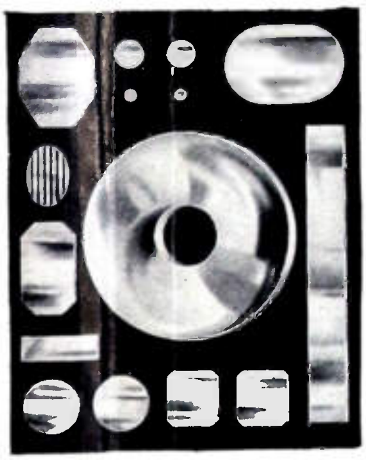
out tuning. It provides check points at fundamental frequencies ranging from 2 to 20 Mc, and has useful harmonics up to at least the sixth.

Two marker pips may be used to set video and *if* circuits and traps, as required by some TV manufacturers, or the variable marker may be brought into coincidence with the crystal marker to check dial reading with crystal frequency or crystal frequency harmonic.

The oscillator provides frequencies ranging from 15 to 240 Mc in four bands: 15 to 30 Mc; 30 to 60 Mc; 60 to 120 Mc; and 120 to 240 Mc. With an appropriate crystal inserted in the panel socket, the oscillator will operate at any frequency between 2 to 20 Mc, and will provide useful harmonic output up to the sixth for all band calibration.

Front-Surface Mirrors

Zenith Optical Laboratory, 123 W. 64 St., New York 23, N. Y., announces the development of their Zeno-Kote process, for producing front-surface mirrors which are durable and tarnish-resistant. The reflecting surface is produced by thermal evaporation of a special aluminum alloy under high vacuum. The reflecting surface is then protected by the deposition of an extremely hard but transparent film, which in no way affects the reflectivity of the mirrors.



Mirrors produced by the Zeno-Kote process have a reflectivity of about 93 per cent in the visible spectrum, and they can be made to meet any optical or dimensional tolerance.

The usual aluminized front-surface mirrors are very delicate and can be cleaned only with great difficulty, whereas front-surface mirrors produced by the Zeno-Kote process can be dusted or wiped without damage to the reflecting surface.

These mirrors are suitable for use in precision electronic and optical equipment, where high and permanent reflectivity characteristics are necessary.

(Continued on page 94A)

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News—New Products

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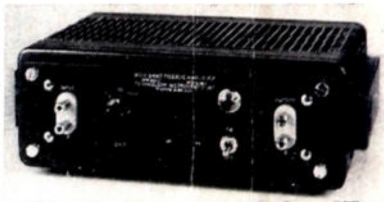
(Continued from page 93A)

CORRECTION NOTICE

Wide-Band Decade Amplifier

Type 500-A wide-band decade amplifier has been developed by **Technology Instrument Corp., 1058** Main St., Waltham, Mass., for general laboratory use and for special applications requiring zero phase shift on high stability of gain. To increase the general utility of the amplifier, compact construction, cabinet or rack mounting, and ac operation from a self-contained power supply have been incorporated in the design.



Input impedance is high enough to permit measurements in most circuits without upsetting normal conditions.

Output impedance is low enough to permit operation into a wide range of loads without causing a variation from the indicated gain of *10, 100 or 1,000 times.*

Maximum output of 20 v on any gain setting insures sufficient amplitude for the operation of most devices used in conjunction with general purpose laboratory amplifiers.

Zero phase shift from 20 cps to 100 kc (all instruments adjusted as close as practical to zero—some might exhibit an error of 2° unless requested otherwise) makes possible the extension of phase measurements *to 5-mv levels,* when used with TIC Type *320 phase meter.*

Gain stabilized by feedback, so that it is constant with line voltage or tube changes.

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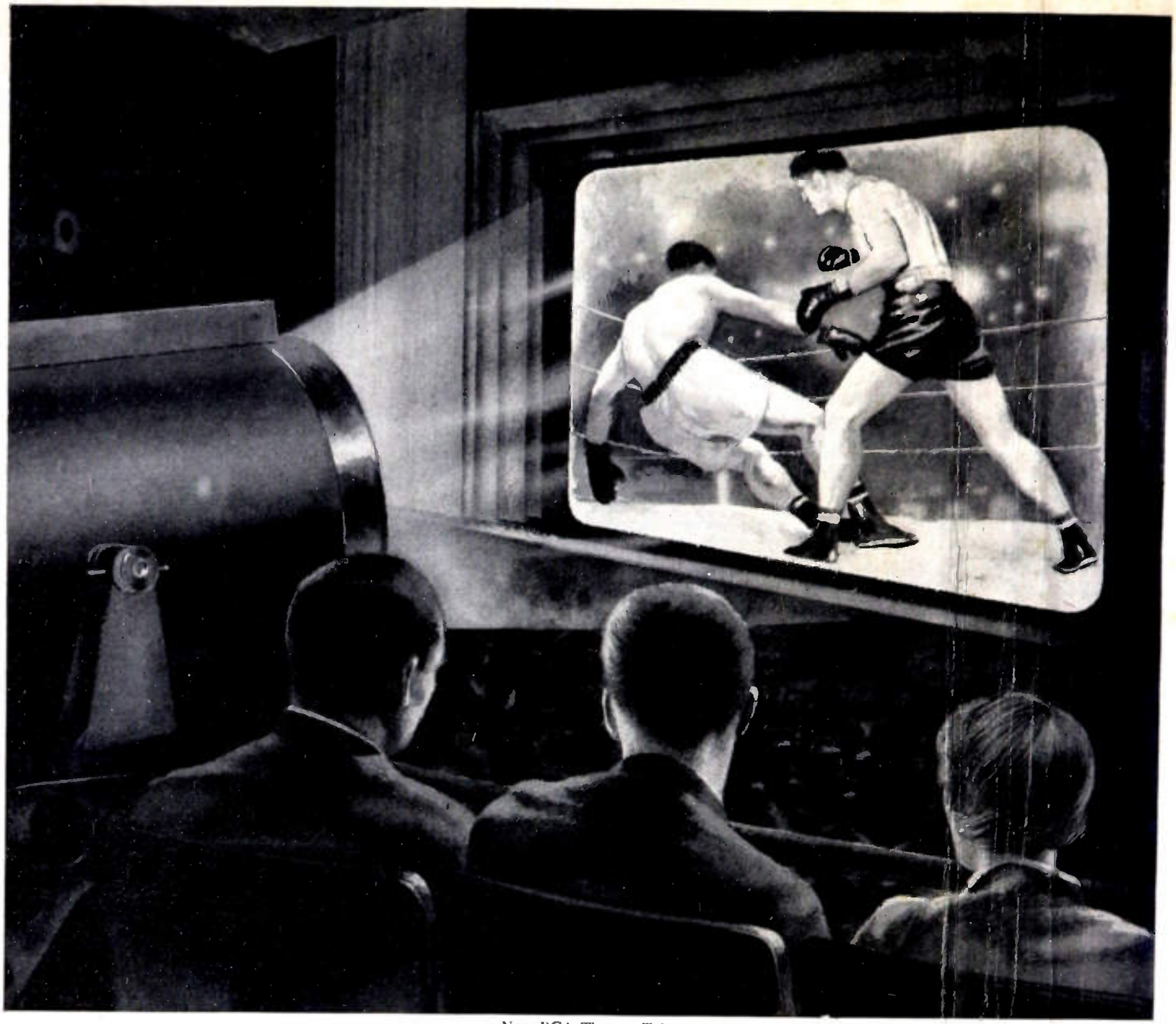
INDEX AND DISPLAY ADVERTISERS

DISPLAY ADVERTISERS



New RCA Theatre Television System projects 15 x 20 foot pictures of television programs.

Giant size Television—"shot from a Barrel!"

You've seen television. Now you'll see it in its finest form—giant projections of special events, transmitted *only* to theatres on private wires or radio beams to make movie-going *better than ever!*

Success of the system comes from a remarkable RCA kinescope, and something new in projection lenses. The kinescope, developed at RCA Laboratories, is in principle the same as the one on which you see regular telecasts. But it is *small*—only a few inches in diameter—and produces images of high brilliance. These are magnified to 15x20 feet by a "Schmidt-type" lens system like those used in the finest astronomical telescopes.

Because of its size and shape, the new projector is referred to by engineers as the "barrel." It's already going into theatres, where you'll be seeing giant television—shot from a barrel.

* * *

See the latest wonders of radio, television, and electronics at RCA Exhibition Hall, 36 West 49th St., N. Y. Admission is free. Radio Corporation of America, Radio City, New York.

The same research laboratories which developed RCA's new theatre television system also give you big, brilliant pictures on 1951 RCA Victor home receivers.

RADIO CORPORATION of AMERICA

World Leader in Radio — First in Television they may look alike, *but:* there is only one C-D

RELIABILITY

Businessmen call it *reputation* . . . accountants refer to it as *goodwill* . . . production men think of it as *reliability*. Reliability has a dollar-and-cents value entirely apart from the quality and price of the capacitors you buy.

That is why so many leading radio equipment manufacturers insist on C-D capacitors. They know that C-D's extensive manufacturing facilities, reliable service, dependable quality are features that cannot be measured in dollars and cents. Typical of this C-D reliability is the:

"Blue Beaver"* Electrolytic

- Special formation process—developed by C-D engineers after years of research — insures low leakage; good performance at high temperatures; long life at high voltages.
- Low contact resistance between anode and lead wires and negative lead to can, by unique assembly procedure. Contact resistance checked on kelvin bridges and maintained at low value.
- Special separator material prevents breakdowns under most adverse conditions.
- A positive acting diaphragm vent — developed in C-D labs — insures proper venting when needed.
- Special insulator around positive lead eliminates shorts to can.
- Extreme care in assembly to eliminate all contamination plus the finest raw materials obtainable insure a unit free from corrosion.

For details on these and other C-D electrolytics write for catalog. CORNELL-DUBILIER ELECTRIC CORPORATION, Dept. M12, South Plainfield, New Jersey. Other plants in New Bedford, Brookline and Worcester, Mass.; Providence, R. I.; Indianapolis, Ind., and subsidiary, The Radiart Corp., Cleveland, Ohio.

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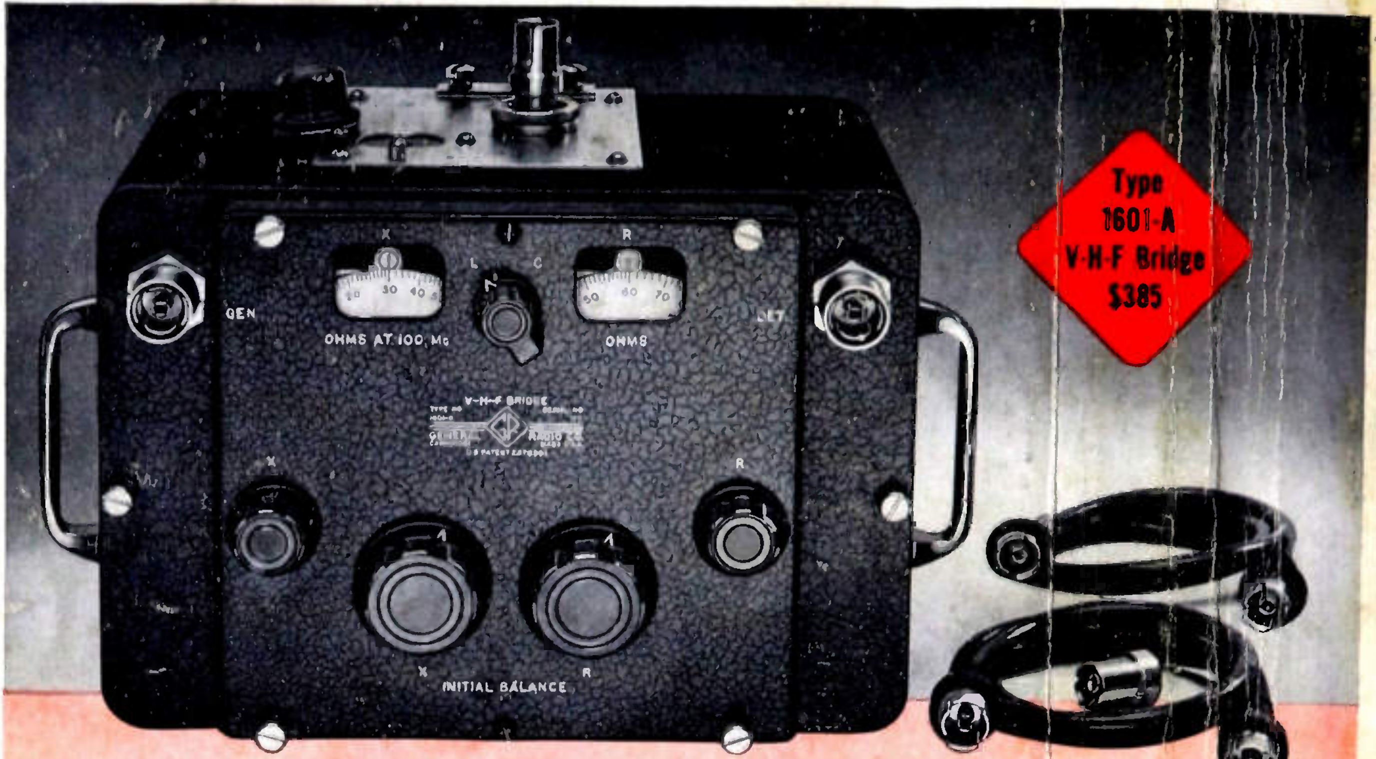

for Bridge Measurements of Impedance

BETWEEN 10 AND 165 Mc

Direct-Reading Resistance Range 0 to 200 OHMS— *independent of frequency except for small corrections.*

Direct-Reading Reactance Range 0 to ±230 OHMS at 100 Mc— *inversely proportional to frequency.*

Coaxial Adapter Supplied for Measurements on Coaxial Systems— *eliminates errors from connecting leads and from residual terminal capacitance. Standing-wave ratio of unknown coaxial system unaffected by terminal capacitance of bridge.*

The Type 1601-A V-F-H Bridge set up to measure the antenns of WCBS-TV on the Chrysler Building, New York City. The antenns consists of 16 radiating elements. Measurements of the impedance variation of an individual element over the operating frequency band as well as impedance measurements of the whole array were made easily and accurately.

THE new Type 1601-A V-H-F Bridge brings to the v-h-f frequencies a means for measurements of impedance of antennas, lines, networks and components, having the same accuracy and simplicity of measurement enjoyed by users of the popular G-R low-frequency Type 916-A R-F Bridge.

With this bridge the range of conventional bridge techniques is extended to 165 Mc. It is equally suited to measurements on coaxial-line systems as on lumped parameter circuits.

It is designed for direct-reading measurements of relatively low impedances, but measures high impedances indirectly and equally well.

For resistance measurements the accuracy is ±(2% + 1 Ω), subject to correction for inductance in the capacitor used to measure the resistance. A correction chart is supplied with the instrument. The ohmic portion of the accuracy statement varies between 0.1 and 1.0 ohm.

For reactance measurements the accuracy is ±(5% + 2 Ω). The ohmic uncertainty varies between 0.1 ohm at 100 Mc and 2 ohms.

This bridge is especially suited to measurements of resistors, capacitors, inductors, transmission-line networks and antennas.

GENERAL RADIO COMPANY Cambridge 39, Massachusetts

90 West St., New York 6 920 S. Michigan Ave., Chicago 5 1000 N. Seward St., Los Angeles 38