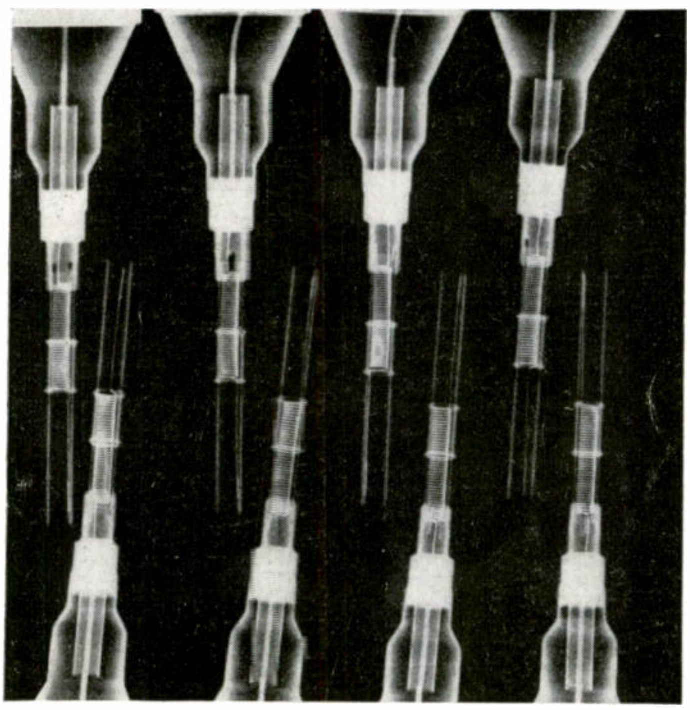
Proceedings of the I·R·E

A Journal of Communications and Electronic Engineering

(Including the WAVES AND ELECTRONS Section)

June, 1948

Volume 36 Number 6



Sylvania Electric Products Inc.

SISTER ELECTRIC TECHNIQUES COLLABORATE

X-rays permit searching inspection of groups of magnetron cathode assemblies.

PROCEEDINGS OF THE I.R.E.

Waves and Electrons Section

TABLE OF CONTENTS FOLLOWS PAGE 32A

The Institute of Radio Engineers

for High Q Inductors...

For Maximum Stability . . . Permalloy Dust Toroids

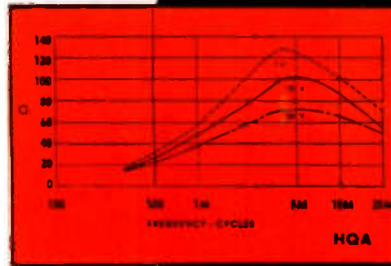
The UTC type HQ permalloy dust toroids are ideal for all audio, carrier and supersonic applications. HQA coils have Q over 100 at 5,000 cycles . . . HQB coils Q over 200 at 4,000 cycles . . . HQC coils Q over 200 at 30KC . . . HQD coils Q over 200 at 60 KC. The toroid dust core provides very low hum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

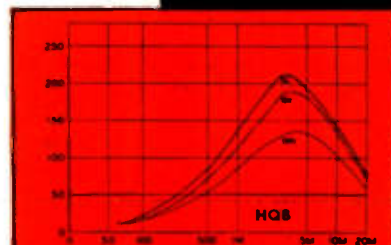
Inductance Value	Type No.	Net Price	Inductance Value	Type No.	Net Price
5 mhy.	HQA-1	$7.00	70 mhy.	HQB-3	$16.00
12.5 mhy.	HQA-2	7.00	120 mhy.	HQB-4	17.00
20 mhy.	HQA-3	7.50	.5 hy.	HQB-5	17.00
30 mhy.	HQA-4	7.50	1 hy.	HQB-6	18.00
50 mhy.	HQA-5	8.00	2 hy.	HQB-7	19.00
80 mhy.	HQA-6	8.00	3.5 hy.	HQB-8	20.00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

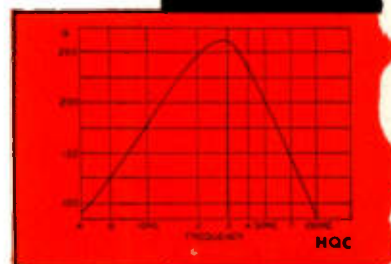
HQA, C, D
1 11/16" Dia. x 1 3/16" High.

HQB
2 5/8" L. x 1 5/8" W. x 2 1/2" H.

UNCASED TOROIDS
(Deduct $1.50 for uncased units)





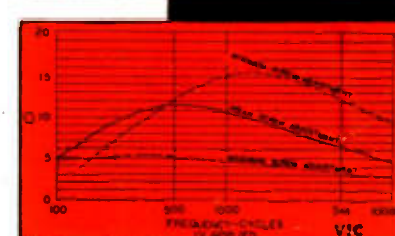


For Maximum Flexibility . . . The VIC Variable Inductor

The set screw on VIC units permits positive adjustment of inductance to plus 90% minus 50% from rated value. Revolutionary approach for tuned audio circuits. Q and L vs. screw adjustment for a typical coil are illustrated.

Type	Mean Hys.	List Price	Type	Mean Hys.	List Price
VIC-1	.0085	$11.00	VIC-11	.85	$14.00
VIC-2	.013	11.00	VIC-12	1.3	14.00
VIC-3	.021	11.00	VIC-13	2.2	14.00
VIC-4	.034	11.00	VIC-14	3.4	14.00
VIC-5	.053	11.00	VIC-15	5.4	16.50
VIC-6	.084	11.00	VIC-16	8.5	16.50
VIC-7	.13	14.00	VIC-17	13	16.50
VIC-8	.21	14.00	VIC-18	21	16.50
VIC-9	.34	14.00	VIC-19	33	16.50
VIC-10	.54	14.00	VIC-20	52	16.50
			VIC-21	83	17.50

1 3/8" L. x 1 1/4" W. x 1 1/2" H.



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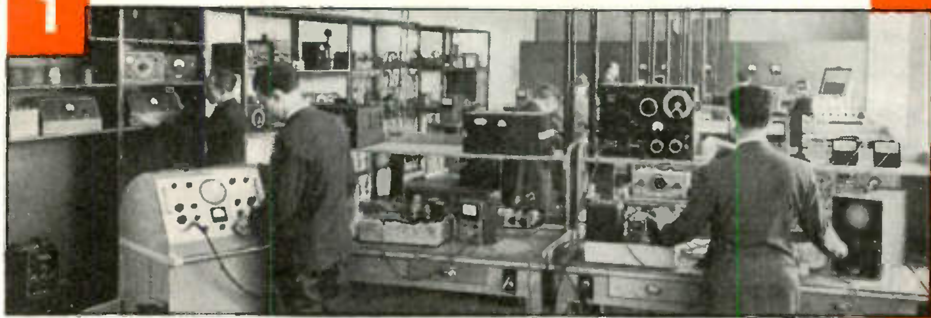
Write for catalog PS-408

What we mean by...

RIGID QUALITY CONTROL

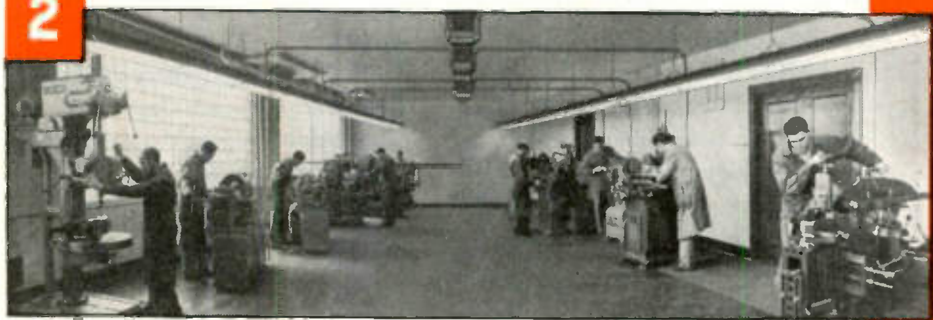
A DEFINITION OF SHERRON METHODS IN THE BUILDING OF CUSTOM MADE ELECTRONICS PROJECTS

1



HERE IN THE SHERRON electronics laboratory we initiate our design and development procedures. Every detail of a project's embryonic phase is explored by thoroughly seasoned physicists, engineers and technicians. Here the pattern for the finished product is accurately defined to assure trouble-free performance.

2



THE SHERRON electro-mechanical laboratory serves in the fabrication of mechanical components for . . . computers, vacuum tube structures, mechanical equipment for electronoptics, special precision wave guides, precision tuning units, precision drive mechanisms, servo mechanisms. Staffed by graduate mechanical engineers, equipped with the newest precision machines and tools, this laboratory is invaluable in closing up the margin for error in the electronic equipment we manufacture.

RECENT SHERRON PROJECTS INCLUDE

COMMUNICATIONS

- *Trans-Receivers for various uses*
- *Television — FM — AM — Transmitters*
- *Navigational Devices, including Homing Equipment, Radar, etc.*
- *Micro-wave techniques and Radio Relay Links*
- *Ample Test Equipment to assure successful operation of above*

ELECTRONIC CONTROL EQUIPMENT FOR

- *Drone Aircraft Guided Missiles*
- *High Gain Amplifiers*
- *Computers and Calculators*
- *Servo Equipment*
- *Velocity Propagation measurement*
- *Test Equipment including Instrumentation for above*

VACUUM TUBE CIRCUIT DEVELOPMENT

- *New applications for existing vacuum tubes*
- *Precision test equipment for vacuum tubes*

CONTROL OF MEASURING DEVICES

- *Flow indicators*
- *Sorting, Counting*
- *Measurement of chemical titrations*
- *Surface strains, stresses, etc.*

INSTRUMENTATION

- *Bridge measurements*
- *Null detectors*
- *Vacuum tube voltmeter-ammeters*
- *Multi-wave shape generators*

TELEVISION

- *Television Signal Synthesizer Sync Generators*
- *Monoscope*
- *Shapers — Timers*
- *Wide band oscilloscopes*
- *Air monitors*
- *Field intensity equipment*
- *Television test equipment*

Sherron Electronics

SHERRON ELECTRONICS COMPANY

Division of Sherron Metallic Corporation

1201 FLUSHING AVENUE • BROOKLYN 6, NEW YORK

PROCEEDINGS OF THE I.R.E., June, 1948. Vol. 36, No. 6. Published monthly in two sections 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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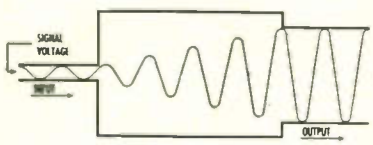
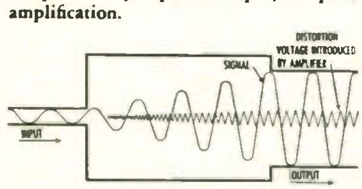
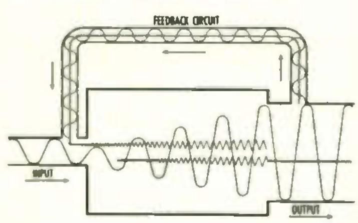
How stabilized feedback reduces amplifier distortion... keeps gain constant



(A) IDEAL AMPLIFIER existing only in theory. Output exactly duplicates input, except for amplification.



(B) AMPLIFIER WITHOUT FEEDBACK. Signal suffers distortion, shown as separate a-c voltage accompanying output signal.



(C) AMPLIFIER WITH STABILIZED FEEDBACK. Sample voltage, containing signal and distortion in same ratio as in output, is fed back in opposing phase to input. Distortion portion is amplified in opposition to distortion arising in amplifier.

LIKE many other major advances in electronics, the development of stabilized (negative) feedback was a direct outgrowth of telephone progress. To produce telephone repeaters with the necessary gain stability and low distortion, H. S. Black, of Bell Telephone Laboratories, took a sample voltage of the amplifier output and fed it back into the amplifier in *opposing* phase. Before-and-after effects are shown in simplified form in the accompanying figures.

How Feedback Reduces Distortion

Signal portion of feedback subtracts from input signal. (In practice, input receives additional amplification to maintain original output voltage.)

Distortion portion, encountering no opposing voltage in input, is amplified in opposition to distortion voltage arising in amplifier. Hence distortion voltage largely cancels itself out — output corresponds closely to input. Noise originating in the amplifier is reduced in a similar way.

How Feedback Stabilizes Gain

The relations of input, output and gain can be shown as follows:

Voltage Gain without Feedback	Total Input	Feedback Voltage (negative)	Net Input (less feedback)	Output	Overall Gain
1000	10.1	10	.1	100	9.9
500	10.2	10	.2	100	9.8

As shown, the gain of the amplifier stages incorporating feedback can drop *50 percent*, with a drop in *overall* gain of only *1 percent*.

Hence *gain remains virtually constant,* regardless of changes in power supply or performance of components.

Users of all line and power amplifiers and all AM transmitters designed by Bell Laboratories and made by Western Electric benefit by these outstanding advantages of stabilized feedback: greatly reduced distortion and noise, virtually constant gain.

AMERICAN TELEPHONE & TELEGRAPH CO. BELL SYSTEM AND ASSOCIATED COMPANIES

BELL TELEPHONE LABORATORIES

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

You get feedback at its finest . . . in Western Electric equipment

While stabilized feedback is now accepted as an indispensable technique in the communications art, ***actual design*** of a stabilized-feedback amplifier calls for painstaking mathematical analysis and control of phase and gain characteristics over a wide frequency spectrum. ***Without such control, feedback may introduce new faults more objectionable than those eliminated.*** The extensive experience of Bell Laboratories engineers gives to the users of Western Electric equipment assurance that the outstanding advantages of feedback will actually be realized.

Assurance of Quality Performance

As used in all Western Electric Audio Amplifiers (except one-tube pre-amplifiers) properly applied stabilized feedback insures flatter gain-frequency characteristic and automatic suppression of noise and distortion arising from sources within the amplifier. In new loudspeaker amplifiers (which include the output coil within the feedback loop), output impedance is so low that matching to multiple loudspeakers is as simple as adding lamps to a lighting circuit.

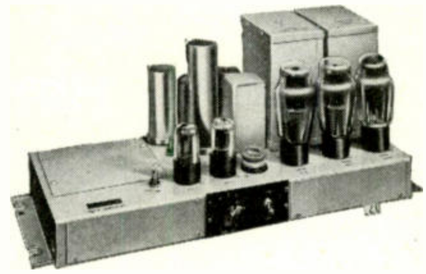
Flat Frequency Response

Flat frequency response is maintained in Western Electric AM Transmitters by stabilized feedback actuated by the final radio frequency output. Hence attenuation of high modulating frequencies is virtually eliminated. No hum suppression circuits are needed, because of reduction of noise and distortion from all sources, including final amplifiers.

Stabilized feedback, correctly applied, is just one of the factors in the outstanding performance of Western Electric Amplifiers and AM Transmitters. For ***full*** information on all operating features, call your local Graybar Broadcast Representative, or write Graybar Electric Company, 420 Lexington Avenue, New York 17, N. Y.

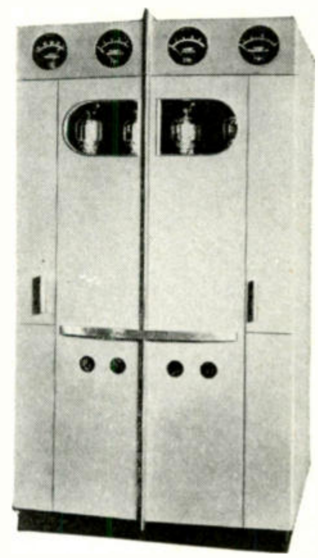
Correctly applied feedback gives you these advantages

IN AMPLIFIERS



Feedback *as you want it* keeps gain virtually constant in Western Electric Audio Amplifiers — cuts noise and distortion down to a minimum.

IN AM TRANSMITTERS



Feedback designed by Bell Laboratories does away with need for hum suppression circuits — maintains flat frequency response.

—QUALITY COUNTS—

Western Electric

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

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THEY KNEW
WHAT THEY WANTED
And, like many other radio engineers, they also knew where to bring their plans for successful completion.
Among recent Blaw-Knox installations is this rugged 500 ft. Special Heavy Duty H 40 Tower for the Crosley Broadcasting Corporation's Station WLWT, supporting a 5-section RCA Television Antenna.
Tower-building experience dating back to the days of "wireless" is at your disposal when you enlist the services of Blaw-Knox engineers.
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2037 FARMERS BANK BUILDING • PITTSBURGH 22, PA.
BLAW-KNOX ANTENNA TOWERS

HOW LONG IS HALF AN INCH?

EL-MENCO's answer is illustrated above — the new miniature CM15. That half inch of silver mica capacitor is miles long on performance . . . age-long on endurance . . . 2 to 500 mmf. long on range.

The CM15 is short on delivery time (unlimited production) . . . short on limitations (tolerances: ± 20% to 1%) . . . short on guess work (6-color coded to Joint Army-Navy Standard Specifications JAN-C-5 for fixed mica dielectric capacitors).

The long and short of it is this: EL-MENCO's new miniature CM15 possesses the value inherent in all EL-MENCO products—

PERFORMANCE • ENDURANCE • RANGE • PRICE • DELIVERY

Write, on firm letterhead, for samples and catalog.

THE ELECTRO MOTIVE MFG. CO., Inc.
WILLIMANTIC, CONNECTICUT

Foreign Radio and Electronic Manufacturers communicate direct with our Export Department at Willimantic, Conn., for information.

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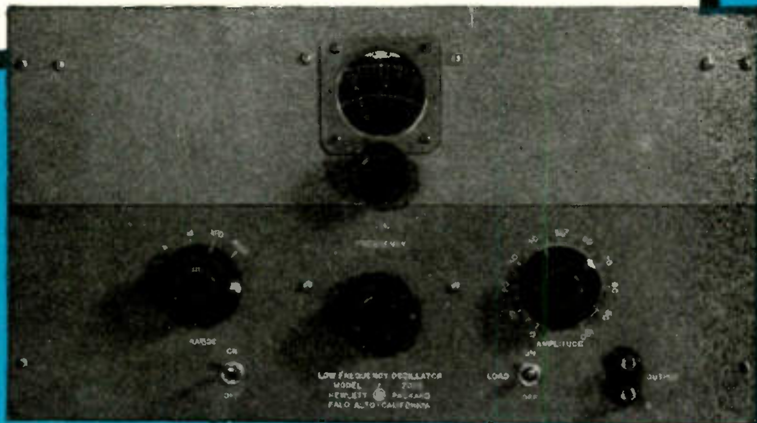
is Sole Agent for El-Menco Products in United States and Canada.

MOLDED MICA El Menco MICA TRIMMER

CAPACITORS

NOW!

A GREAT NEW *hp* OSCILLATOR FOR THE LOW-FREQUENCY FIELD



½ to 1000 CYCLES

-hp- 202B LOW-FREQUENCY OSCILLATOR

Now, for the first time in history, you can make low frequency measurements with all the precision and stability associated with audio frequency work. This great new *-hp-* oscillator blankets the low-frequency spectrum from ½ to 1000 cps. Throughout this range it provides better wave form, higher stability and greater measuring accuracy than any comparable instrument ever manufactured for industrial, field or laboratory use.

Compact, sturdy, easy-to-operate, this *-hp-* 202B spans the low-frequency band in 4 ranges. Frequency is read on a large, illuminated dial, which is controlled by a direct or a 6 to 1 vernier drive. Frequency stability is within ±5%, including initial warm-up drift. Output is 10 volts maximum into a 1000 ohm resistive load.

The rugged practicality, low cost and unusual versatility of this brand new *-hp-* oscillator make it an essential instrument for any operation involving low frequency work. The *-hp-* 202B is ready for early shipment. Write or wire for full information.

HEWLETT-PACKARD COMPANY
1470D Page Mill Road • Palo Alto, California

SPECIFICATIONS

FREQUENCY RANGE: ½ cps to 1000 cps in 4 ranges

Range	Frequency
A	½ - 1 cps
X1	1 - 10 cps
X10	10 - 100 cps
X100	100 - 1000 cps

FREQUENCY DIAL: 6" diameter. Reads directly in cps for two lower ranges. Dial is back of panel, illuminated, and is controlled by direct drive as well as a 6 to 1 vernier.

ACCURACY OF CALIBRATIONS: ±2%

FREQUENCY STABILITY: ±5% under normal temperature conditions (including warm-up drift). Less than ±1% for power voltage changes of ±10%.

OUTPUT: 10 volts into a 1000 ohm resistive load over the entire frequency range. Internal impedance approximately 25 ohms at 10 cps.

FREQUENCY RESPONSE: ±1 db 10-1000 cps; ±2 db 1-1000 cps

DISTORTION: Less than 1% total distortion 1 cps to 1000 cps.

HUM VOLTAGE: Less than 0.1% of rated output voltage.

This *-hp-* 202B gives maximum speed and accuracy for these important tests

•

Vibration or stability characteristics of mechanical systems

Electrical simulation of mechanical phenomena

Electro-cardiograph and electro-encephalograph performance

Vibration checks of aircraft structural components

Checking geophysical prospecting equipment

Response of seismographs

1470

hp laboratory instruments

FOR SPEED AND ACCURACY

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

CLASS OF THE POWER-TUBE FIELD FOR FM AND

TELEVISION

GL-9C24 V-h-f Triode

- **POWER TO SPARE... two tubes "under wraps" will put out more than 10 kw in FM—more than 5 kw in television.**
- **FREQUENCY UP TO 220 MC at max plate input.**
- **All the electrical characteristics of ULTRA-MODERN H-F TUBE DESIGN.**
- **Sturdy and COMPACT for close side-by-side tube mounting.**
- **G-E RING SEAL construction gives generous terminal-contact areas.**

RATINGS

Filament voltage	6.3 v
Filament current	240 amp
Grid-plate transconductance	11,000 micromhos
Interelectrode capacitances:	
Grid-filament	24 micromicrofarads
Grid-plate	15.7 micromicrofarads
Plate-filament	0.5 micromicrofarads
Type of cooling	water and forced air
Plate ratings per tube, Class B r-f power amplifier (video service, synchronizing peak conditions):	
Max voltage	5,000 v
Max current	2 amp
Max input	10 kw
Max dissipation	5 kw
* Useful power output, typical operation (at 4,000 v and 1.7 amp, band width 5 mc)	3.4 kw
Plate ratings per tube, Class C r-f power amplifier (key-down conditions without modulation):	
Max voltage	6,500 v
Max current	2 amp
Max input	12 kw
Max dissipation	5 kw
* Useful power output, typical operation (at 6,000 v and 1.3 amp)	6.4 kw

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

TODAY'S better pictures, in many cases, owe a debt for sharpness and quality to the superior signal put on the air by General Electric's great power triode, GL-9C24. Newest transmitters with finer video performance, use GL-9C24's in push-pull for final output over both low and high-band channels.

In FM work, too, this tube has set noteworthy standards. With ratings in frequency and power that are ideal for the job—plus a wholly new design concept which outmodes earlier v-h-f types—the GL-9C24 is an example of detailed planning for efficiency.

When applied in a properly designed grounded-grid amplifier circuit, *no neutralization is necessary.* Lead inductance is extremely low. External metal parts are silver-plated, to cut r-f losses and provide better electrical contact surfaces. Fernico metal-to-glass seals are used throughout . . . this tube is long-lived, sturdy!

If you build transmitters and wish to benefit from the proved brilliant performance of Type GL-9C24, your nearby G-E electronics office gladly will give you further details.

If you are a station operator or engineer, needing replacement tubes *of any type*—FM, television, or AM—see your local General Electric tube distributor or dealer for alert service! Besides showing the way in tube design, G.E. gets tubes to you fastest when you need them. *Electronics Department, General Electric Company, Schenectady 5, N. Y.*

GENERAL ELECTRIC

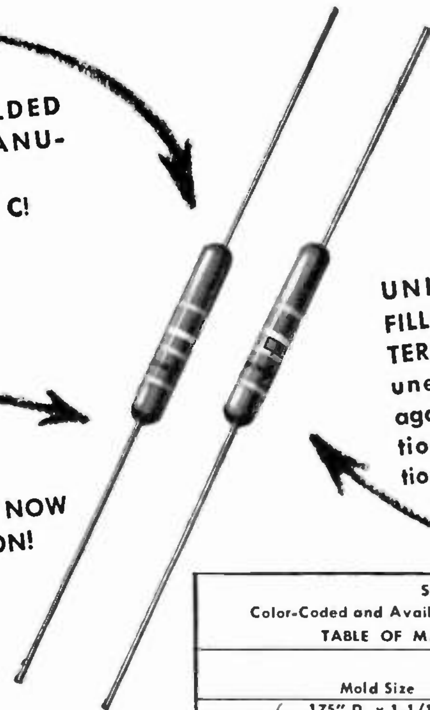
161-G4-8850

FIRST AND GREATEST NAME IN ELECTRONICS

A QUIET REVOLUTION IN CAPACITOR DESIGN

ACTUAL SIZE ILLUSTRATION TYPE 65P

THE SMALLEST MOLDED TUBULAR EVER MANUFACTURED! . . . and rated up to 125° C!



UNIQUE, MINERAL-FILLED MOLDING MATERIAL! . . . Provides unequalled protection against moisture absorption even under conditions of extreme humidity!

A PROVEN PRODUCT NOW IN MASS PRODUCTION!

Seven Physical Sizes
Color-Coded and Available in 20%, 10% and 5% Decade Values
TABLE OF MAXIMUM NOMINAL CAPACITIES

	Mold Size	100V @ 125° C.	200V @ 85° C.*	400V @ 85° C.	600V @ 85° C.
65 P	.175" D. x 1-1/16"	.015	.01	.0068	.0022
	.195" D. x 1-1/16"	.022	.015	.01	.0033
	.250" D. x 1-1/16"	.047	.033	.022	.0068
	.375" D. x 1-1/16"	.15	.1	.068	—
75 P	.175" D. x ¾"	.0068	.0047	.0033	.001
	.200" D. x ¾"	.01	.0068	.0047	.0015
	.250" D. x ¾"	.022	.015	.01	.0033

* alternate rating 150V @ 125° C.

NEW SPRAGUE MOLDED PROKARS*

. . . dependable capacitors for sub-miniature assemblies

SUB-MINIATURE PAPER CAPACITORS IN METAL CANS WITH HERMETIC, GLASS-TO-METAL SEAL

•

for the most severe applications

•

Yes, this little can houses a high quality hermetically sealed Paper Capacitor! Rated at 100 volts, D C Working, this .5 mfd. unit measures .4" x 1⅛". Presently being manufactured in quantity, variations of this sub-miniature type can be made to your specifications. Write for complete information about this and even smaller hermetically sealed units now in production as shown below.

These new molded Prokars were designed specifically to satisfy stringent military requirements. Types 65P & 75P are now in mass production and are available in a wide range of capacities—from .00047 mfd. to .15 mfd! Though higher in price than standard units, they easily justify the term "premium" in performance. Rated for —50° C to 125° C operation, these small but rugged units are ideally suited for any electrical or electronic application in which size, temperature, humidity and physical stress are dominant considerations.

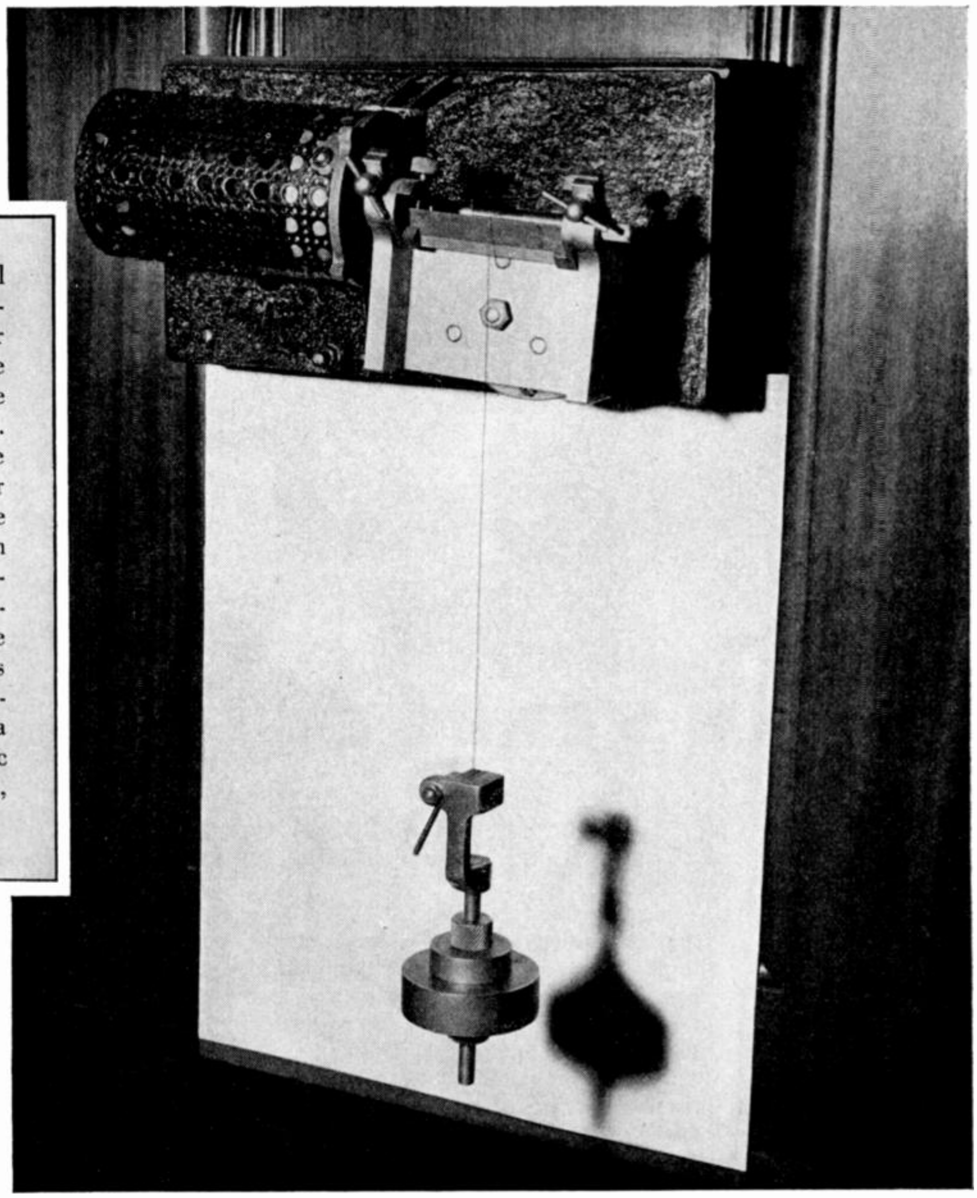
*T. M. Reg. U. S. Pat. Off.

Write for Engineering Bulletin No. 205 A

SPRAGUE

SPRAGUE ELECTRIC COMPANY,
NORTH ADAMS, MASS.

PIONEERS OF ELECTRIC AND ELECTRONIC PROGRESS



Specify **HI-Q** COMPONENTS

for **PRECISION . . .**

Precision standards are set in the laboratory.

● Accurate performance of your product is limited by the precision of its component parts. It is only through selection of precision components that superior performance can be assured. Hi-Q Ceramic Capacitors, for example, can be held to a minimum tolerance of .25 MMF. Constant surveillance throughout every stage of manufacture . . . from raw material to finished product . . . is responsible for this uniformly high quality of all Hi-Q components. Specify Hi-Q components . . . your assurance of precision performance.

CERAMIC CAPACITORS

Hi-Q Ceramic Capacitors of unquestionable stability assure you the ultimate in performance for all electronic appliances. Let us assist you with your Ceramic Capacitor problems.

CHOKE COILS

STAND-OFF CONDENSERS

WIRE WOUND RESISTORS

HI-Q COMPONENTS BETTER 4 WAYS

PRECISION Tested step by step from raw material to finished product. Accuracy guaranteed to your specified tolerance.

UNIFORMITY Constancy of quality is maintained over entire production through continuous manufacturing controls.

DEPENDABILITY Interpret this factor in terms of your customers' satisfaction . . . Year after year of trouble-free performance. Our Hi-Q makes your product better.

SPACE SAVING The smallest BIG VALUE components in the business make possible space saving factors which reduce your production costs . . . increase your profits.

HI-Q

Electrical Reactance Corp.

FRANKLINVILLE, N. Y.

Plants: FRANKLINVILLE, N. Y. — JESSOP, PA.

Sales Offices: BOSTON, NEW YORK, PHILADELPHIA, DETROIT, CHICAGO, LOS ANGELES

Presenting

DURANITE

THE SUPERIOR CAPACITOR

In several sizes. This size 1½" long by ½" diameter.

● Aerovox proudly presents a basically new capacitor designed and produced to meet today's more critical requirements.

Duranite capacitors are not to be confused with conventional molded tubulars encased in usual materials. Duranite capacitors are *entirely new*—Aerolene, the *new* impregnant; the *new* processing methods; the *new* Duranite casing—all adding up to an *entirely new* concept in the capacitor art.

Note some of Duranite's extraordinary features herewith presented! Make comparative tests! You be the judge!

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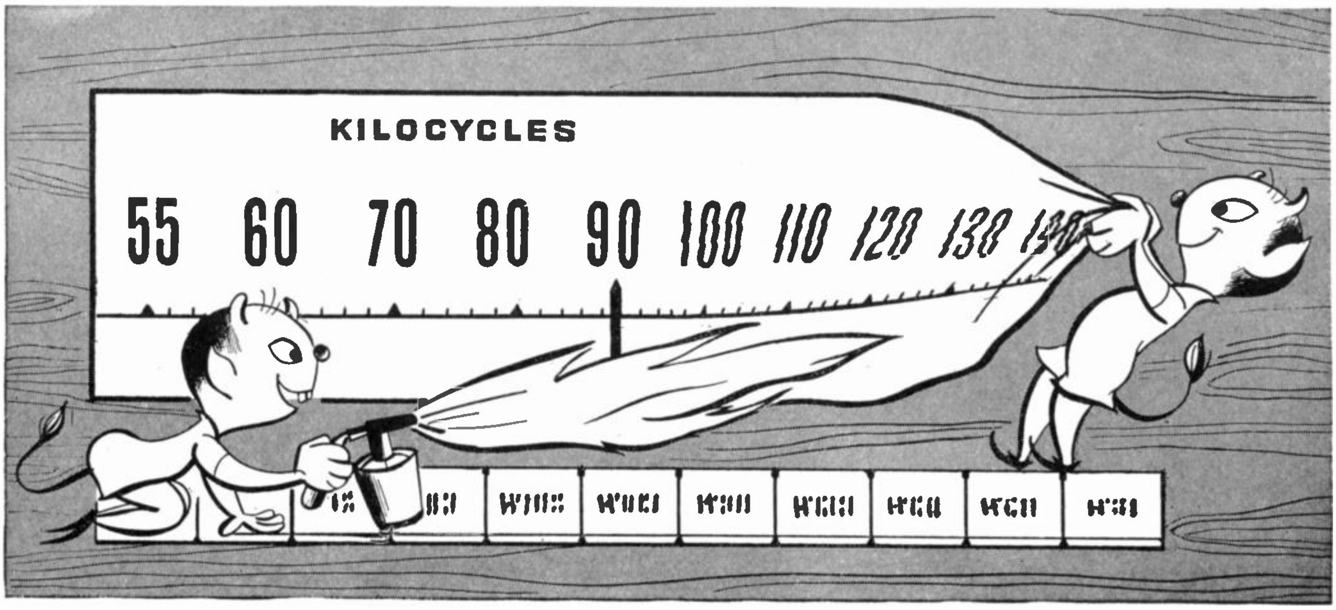

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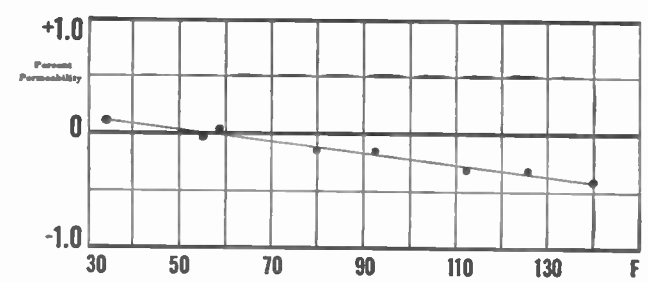

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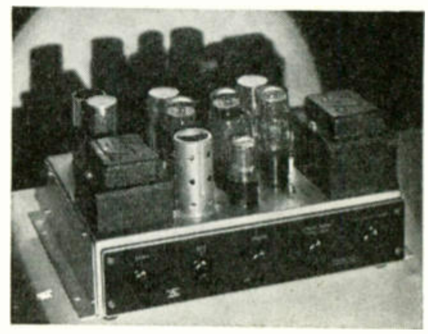
The Type 210-A laboratory amplifier, offered by **Hermon Hosmer Scott, Inc.**, Dept. IR, 385 Putnam Ave., Cambridge, Mass., uses the dynamic-band-pass principle to reach new peaks of performance. In addition to reproducing phonograph records, the amplifier may be used with any standard tuner, and is designed to provide quality reproduction of phonograph records, f.m., or a.m.



This unit, supplied with a matched variable-reluctance pickup cartridge, provides a complete phonograph system except for turntable or record changer and loudspeaker. The amplifier provides 20 watts output with less than 2% distortion, and below 8 watts, the distortion is under ½%. The output transformer is arranged to match speaker impedances between 2 and 500 ohms.

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(Continued on page 55A)

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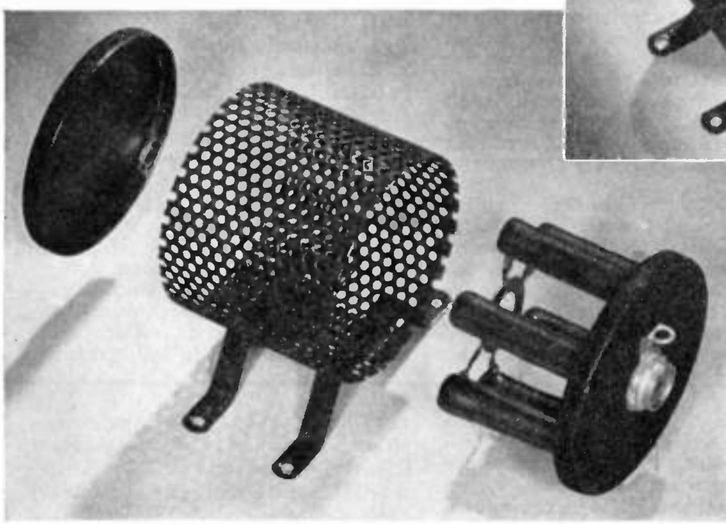

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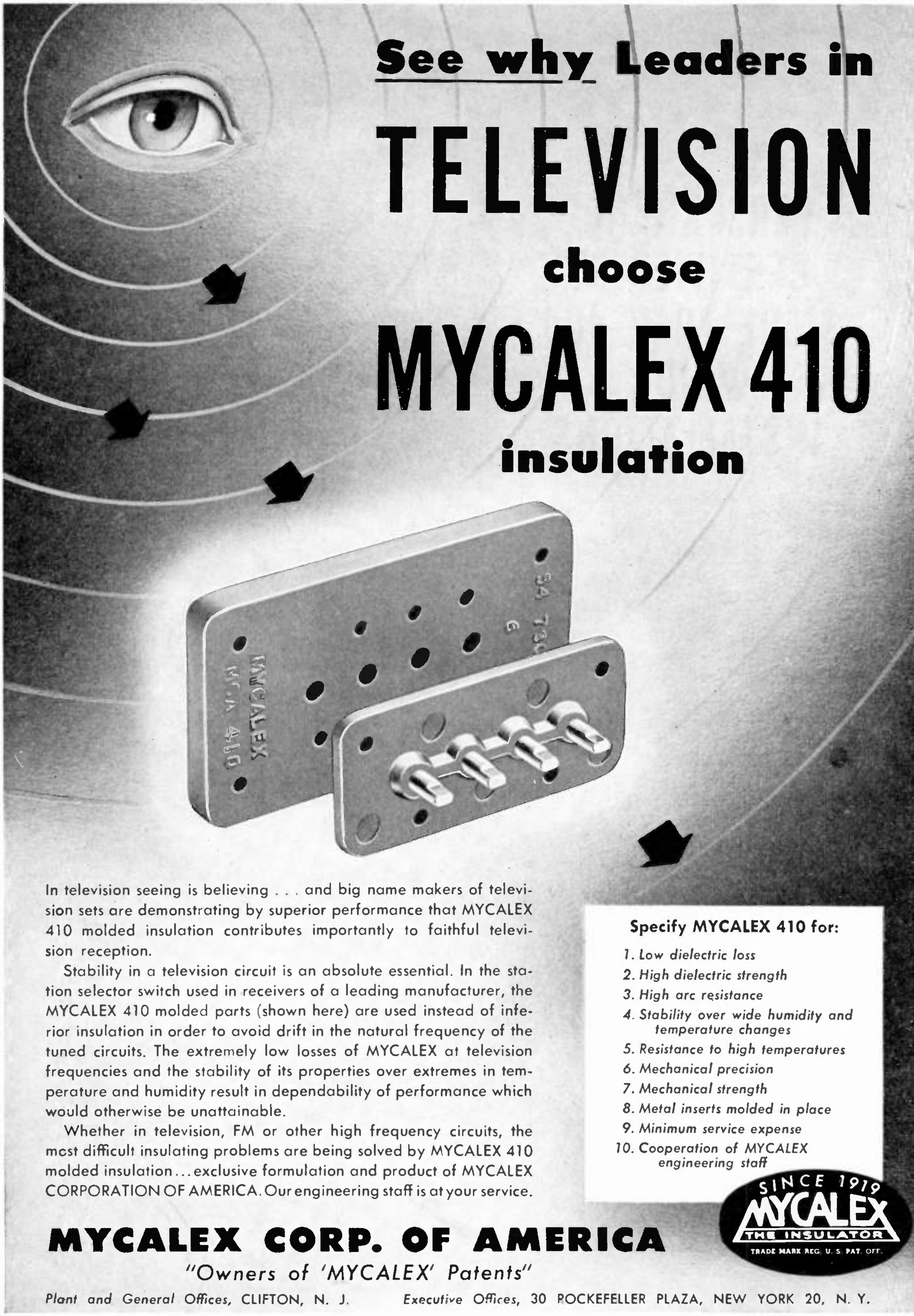
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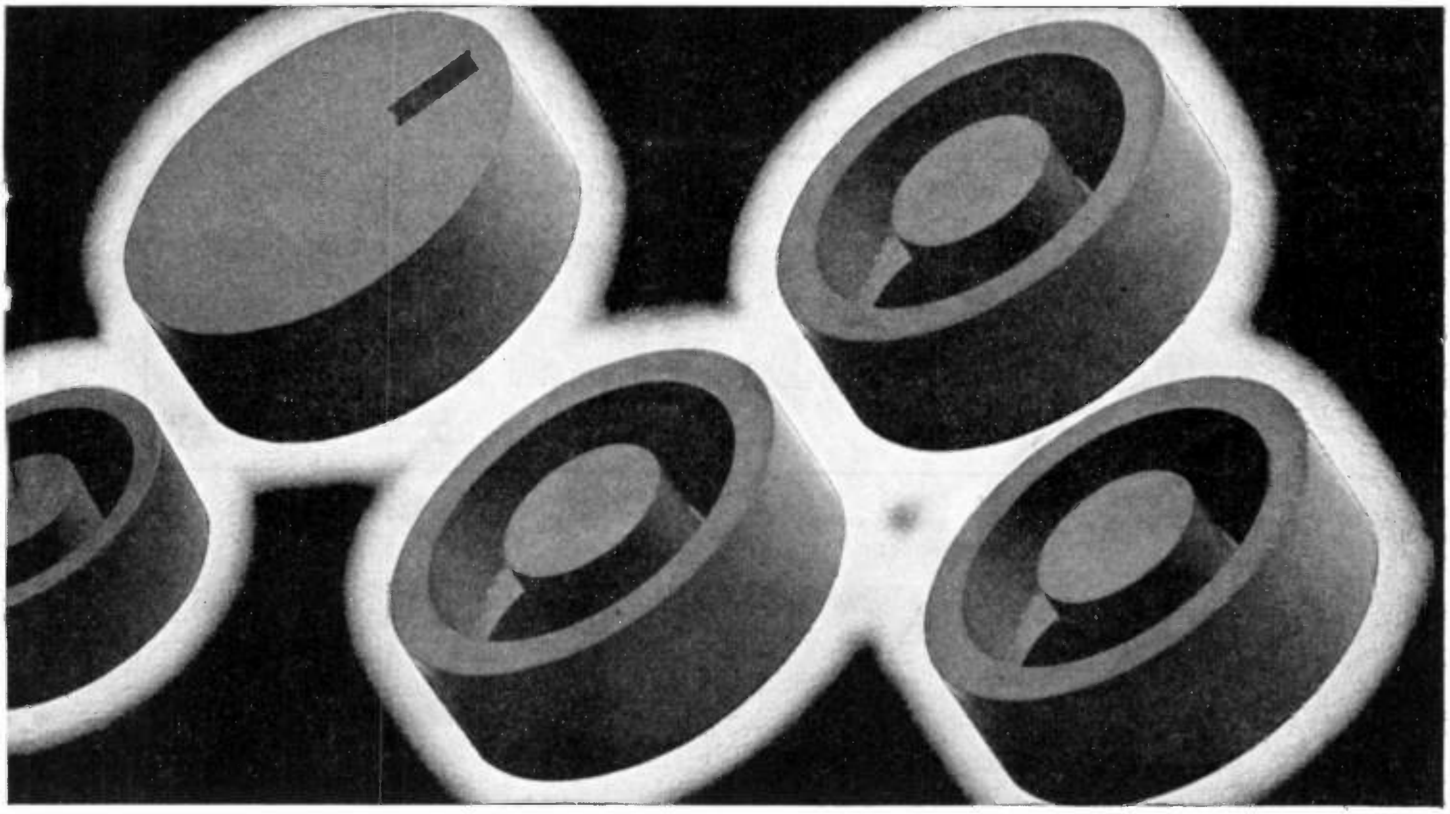

PROCEEDINGS OF THE I.R.E.

(Including the WAVES AND ELECTRONS Section)

Published Monthly by

The Institute of Radio Engineers, Inc.

VOLUME 36 — *June, 1948* — NUMBER 6

PROCEEDINGS OF THE I.R.E.

INSTITUTE NEWS AND RADIO NOTES SECTION

WAVES AND ELECTRONS SECTION

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MEMBER AUDIT BUREAU OF CIRCULATIONS

Herbert J. Reich

Director, 1948–1949

Herbert J. Reich, educator and author, was born on Staten Island, New York, on October 25, 1900. He received the M.E. degree in 1924, and the Ph.D. degree in physics in 1929 from Cornell University.

In 1929 Dr. Reich became associated with the University of Illinois as assistant professor of electrical engineering, and was advanced to the rank of associate professor in 1936, and professor in 1939. On January 1, 1944, he was granted leave of absence to join the staff of the Radio Research Laboratory at Harvard University. He was appointed professor of electrical engineering at Yale University in January of 1946, and has remained in this position to date.

Dr. Reich specialized in the field of electron tubes and electron-tube circuits and has published approximately forty-five papers on these and related subjects in technical periodicals. He is the author of "Theory and Application of Electron Tubes," "Principles of Electron Tubes," co-author of "Ultra-High-Frequency Techniques," and editor of "Very-High-Frequency Techniques."

He was elected to Associate membership in The Institute of Radio Engineers in 1926, and transferred to Member grade in 1941. In 1943 he became a Senior Member. He has served on numerous committees and at present is a member of the Board of Editors, the Electron Tube Committee, and the Education Committee. During 1944 he was a member of the Board of Directors. He is also 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.

Between the alternatives of a productive and happy future for mankind and the dread prospect of the utter annihilation of painfully won accomplishments of civilization lies only the power of an idea. That idea—international understanding through good will, intelligent co-operation, and reasonable mutual adjustments—has proved its worth in difficult and contentious fields. It is clearly set forth and urged for acceptance in the following guest editorial by Dr. J. H. Dellinger, Chief of the Central Radio Propagation Laboratory of the National Bureau of Standards of the United States, capable representative of his country at many international radio conferences, and a Past-President and Fellow of The Institute of Radio Engineers.—*The Editor.*

The Great Opportunity

J. H. DELLINGER

To be sure, the vast field of radio and electronics offers vast opportunity. It is the very symbol of progress. But there is a unique aspect of its potentialities which has not received sufficient emphasis. That is its opportunity to contribute to world friendliness, the prerequisite of world peace. This opportunity includes much more than broadcasting, which has long taken its place as a mighty enlightener and leveler of barriers between nations. High hopes were entertained twenty-five years ago, when the wonders of broadcasting were revealed, that this would be the means of achieving world-wide understanding. Its force in that direction is not to be underestimated, but it is not enough. To help in the present critical fight for world peace, we can offer, besides broadcasting, the special contributions of radio business and radio science, the physical nature of radio in its world-wide effects, and the very difficulties of control of radio interference. All of these involve powerful forces toward international collaboration, and we must consciously use them to that end.

Despite its constant repetition, people do not realize, at this juncture of world affairs, the awful need for real international understanding. The entire population of the world is now defenseless against destruction should war come again. There is no alternative: world collaboration has to be achieved. There is no simple and no single way. Every path must be followed and we must all do whatever we can. When Einstein forsakes his equations to preach this and this alone, the world should realize its supreme truth. When Haraden Pratt and Arthur Van Dyck forsake their business duties long enough to see what the atomic bomb can do and come out with the same answer (see what they said on page 933 of the PROCEEDINGS OF THE I.R.E., vol. 34, December, 1946), we radio men should stop and think what we can do about it.

We are privileged to work in a field which does promote international understanding. First of all, radio business and radio science provide unusually extensive contacts at the international level. With our electronic products we export not only goods but ideas and all sorts of personal contacts. The many ramifications of these activities likewise cause us to import the offerings of other countries. In all of this, radio men have the opportunity to display those principles of fair dealing and mutual respect which are a major ingredient of permanent peace among men.

The physical nature of radio phenomena requires radio scientists, engineers, and business men to think on a world scale. The establishment and maintenance of long-distance communication, of ship radio service, of navigation aids to the world's airways, require common action by men of different nationalities. The vagaries of radio transmission require world-wide collaboration and utilization of radio propagation data.

Radio simply could not operate without world collaboration in the control of interference. Radio waves recognize no national or other boundaries. We all use the same transmission medium and we cannot tune in the stations we want and tune out the ones we don't want without very detailed world agreements on the use of the radio spectrum. The preparation and revision of these world agreements provide an exceptionally fine demonstration of the possibilities of whole-hearted international collaboration. I have participated in many of them, from that of Paris in 1921 to the recent ones of Rio, Moscow, and Atlantic City. I know that men of all nations can work out together the most complicated and difficult problems, even with national sovereignties deeply affected, in the spirit of true friendliness and with complete success, for I have seen them do it. This process is going on even now: at Geneva, Switzerland, an international body of engineers and administrators is working the whole of this year to develop a new, improved assignment of the world's long-distance frequencies.

I may be pardoned for closing on a personal note. I have been especially fortunate in being associated with many aspects of radio science, engineering, and administration, and in being selected to serve as a representative of the radio engineering profession in some of them. I have seen the forces of good will at work between radio men of different nations. I deeply believe that these currents of good will and international friendliness are by no means negligible contributions to the happier world future.

A Low-Noise Amplifier*

HENRY WALLMAN†, ASSOCIATE, I.R.E., ALAN B. MACNEE†, ASSOCIATE, I.R.E., AND C. P. GADSDEN‡, MEMBER, I.R.E.

Summary—**This paper describes an amplifier circuit which yields very low noise factor, consisting of a grounded-cathode triode followed by a grounded-grid triode. The combination is entirely noncritical and provides the low noise factor of a triode with the high amplification and stability of a pentode. Noise factors averaging 0.25 db at a carrier frequency of 6 Mc. and 1.35 db at 30 Mc. have been achieved. Typical circuit details are given.**

I. Introduction

IN COMMUNICATIONS systems in which the minimum usable signal is determined by receiver noise, as distinct from noise arising from atmospherics,[1] jamming, etc., improving receiver noise factor[2,3] is as valuable as increasing transmitter power. The amplifying arrangement described in this paper affords a reduction of about 2 db in the minimum perceptible signal of certain microwave radar receivers; this is equivalent to increasing peak power in the associated transmitters from 1.0 to 1.6 megawatts, at vastly less cost.

It is well known that the random division of cathode current between plate and screen in a pentode makes the shot-noise current of a given pentode about three to five times that of the same tube connected as a triode with screen strapped to plate.[4] This effect is called "partition noise"; because of it, many suggested arrangements for obtaining good amplifier noise factor have revolved around the use of a triode as a first stage.[5–7]

A triode can be employed in three ways; namely, as a grounded-cathode stage, a grounded-grid stage, or a grounded-plate stage (cathode-follower). For a given tube type, these three configurations can be shown to yield, very closely, the same noise factor. If a single triode is used to precede a pentode amplifier chain, and if any triode load resistors necessary for stability are considered to be part of the triode stage, then all these arrangements have the disadvantage in wide-band amplifiers (1 Mc. or wider) that the available gain[8] is low. The noise factor of the complete amplifier is, consequently, materially affected by the noise factor of the remainder of the amplifier, in accordance with the relation[3]

$$F_{12} = F_1 + \frac{F_2 - 1}{G_1} \tag{1}$$

where

F_{12} = noise factor of entire amplifier

F_1 = noise factor of first stage

F_2 = noise factor of balance of amplifier with source resistance equal to the output resistance of the first stage

G_1 = available gain of first stage.

This circumstance suggests the desirability of using a triode as a second stage also, either to make F_2 small or, as is done in the circuit described below, to permit stability to be maintained with a large value of G_1.

Two triodes can be cascaded in nine possible ways. Theoretical and experimental investigation of these nine possibilities led us to the one described below as being the best combination, with regard to noise factor, stability, and gain.

The arrangement in question was devised by the authors in 1944 at the M.I.T. Radiation Laboratory. It consists of a grounded-cathode triode first stage, followed by a grounded-grid triode second stage. An a.c. diagram is shown in Fig. 1. The various coils are midband resonant with their associated capacitances.

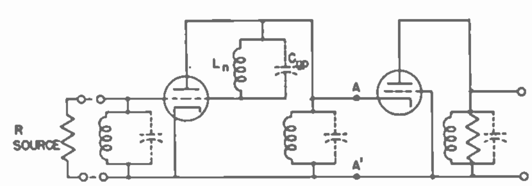


Fig. 1—A.c. diagram of cascode low-noise amplifier.

The coil L_n in parallel with the grid-plate capacitance C_{gp} is a neutralizing coil whose purpose is, however, not to obtain stability but to achieve low noise factor. Even in amplifiers operating at a midband frequency as high as 180 Mc., L_n can be omitted with complete preservation of stability, although the noise factor is increased from 5.5 to 8.0 db.

Search for a concise name for the grounded-cathode, grounded-grid combination led to the designation "cas-

* Decimal classification: R363. Original manuscript received by the Institute, December 4, 1947. Presented, 1948 I.R.E. National Convention, March 23, 1948, New York, N. Y.

† Massachusetts Institute of Technology, Cambridge, Mass.

‡ Tulane University, New Orleans, La.

[1] K. G. Jansky, "Minimum noise levels obtained on short-wave radio receiving systems," Proc. I.R.E., vol. 25, pp. 1517-1530; December, 1937.

[2] D. O. North, "The absolute sensitivity of radio receivers," *RCA Rev.*, vol. 6, pp. 332–344; January, 1942.

[3] H. T. Friis, "Noise figures of radio receivers," Proc. I.R.E., vol. 32, pp. 419–422; July, 1944.

[4] B. J. Thompson, D. O. North, and W. A. Harris, "Fluctuations in space-charge-limited currents at moderately high frequencies," *RCA Rev.*, vols. 4 and 5; January, 1940, to July, 1941.

[5] M. C. Jones, "Grounded-grid radio-frequency voltage amplifiers," Proc. I.R.E., vol. 32, pp. 423–429; July, 1944.

[6] Milton Dishal, "Theoretical gain and signal-to-noise ratio of the grounded-grid amplifier at ultra-high frequencies," Proc. I.R.E., vol. 32, pp. 276–284; May, 1944.

[7] G. C. Sziklai and A. C. Schroeder, "Cathode-coupled wide-band amplifiers," Proc. I.R.E., vol. 33, pp. 701–708; October, 1945.

[8] Throughout this paper, gain refers to power ratios, and amplification to voltage ratios.

code," after a somewhat similar arrangement employed by Hunt and Hickman.[9]

The cascode amplifier shown in Fig. 1 provides (a) the stability and noncriticalness of a pentode, (b) the amplification and gain of a pentode, and (c) the low noise factor of the first triode.

It is the two triodes together that have the amplification of a single pentode; thus the cost of the improvement in noise factor is one additional tube. It is possible, however, that a high-quality double triode with separate cathodes, such as the recently announced type 2C51, may yield the advantages of this circuit with only one envelope.[10]

Conventional pentode amplifier stages follow the cascode to provide the bulk of the amplifier gain.

The cascode low-noise amplifier was used for wide-band band-pass amplifiers, and can be applied a fortiori to narrow-band amplifiers; with this technique, it should be possible to build 30-Mc. communications receivers with noise factors of 1.4 db.

It is believed that the low-noise cascode circuit can also be adapted to low-pass amplifiers.

II. Grounded-Cathode Amplifiers

For use in the subsequent discussion, we now summarize the noise-factor analysis of a grounded-cathode amplifier stage.[4,11] The analysis is made for midband frequency, at which the various tube and circuit capacitances are assumed to be resonated out.

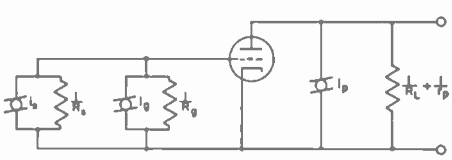


Fig. 2—Equivalent circuit for band-center noise-factor analysis of grounded-cathode stage.

The amplifier can then be analyzed in terms of the equivalent circuit of Fig. 2, where

- k = Maxwell-Boltzmann constant (1.38×10^{-23} joule/°K.)
- T = absolute temperature of source resistance (usually taken as 290°K., "room temperature")
- B = noise bandwidth
- R_s = transformed source resistance
- R_g = input resistance due to tube and coupling circuits
- g_m = tube mutual transconductance
- r_p = tube plate resistance
- R_L = load resistance
- $\overline{i_s^2}$ = mean-squared thermal-agitation-noise current, $4kTB/R_s$, of R_s
- $\overline{i_g^2}$ = mean-squared grid-noise current
- T_g = effective absolute temperature of the input loading, defined as $\overline{i_g^2}R_g/4kB$
- $\overline{i_{ns}^2}$ = mean-squared tube-shot-noise current
- $\overline{i_{nr}^2}$ = mean-squared thermal-agitation-noise current, $4kTB/R_L$ of R_L
- $\overline{i_p^2}=\overline{i_{ns}^2}+\overline{i_{nr}^2}$ = mean-squared plate-circuit noise current.

Although the tube in Fig. 2 is shown as a triode, it can also be a tetrode or pentode, provided all electrodes other than the control grid and plate are by-passed to ground over the frequency range to be amplified.

For convenience of notation, it is common in noise-factor analysis to replace an actual tube with plate-circuit noise current i_p by a fictitious noiseless tube, having in series with its signal grid lead a noise voltage

$$e_{eq} = i_p/g_m \tag{2}$$

which, when amplified by the tube, produces in its plate circuit the noise current i_p. It is then possible to define a purely fictitious resistance R_{eq} according to the relation

$$R_{eq} = \overline{e_{eq}^2}/4kTB, \tag{3}$$

called the equivalent noise resistance of the grounded-cathode stage.[12] As a measure of the noisiness of the tube and its load resistor, R_{eq} is a schematic substitute for the plate-noise current i_p.

If there is a coupling circuit between the signal source and the tube grid, R_s and i_s are regarded as the source resistance and the corresponding noise current referred to the output terminals of the coupling circuit.

The shunt input loading $1/R_g$ is made up of three components: tube loading due to cathode-lead-inductance feedback, transit-time loading, and loading due to losses in the input circuit. In noise analyses, the cathode-lead inductance can be considered to be zero or tuned out by a suitable series capacitor, for it has been shown[13] that if this were not the case the resulting input loading would have only second-order effect on amplifier noise factor, because it degenerates tube noise as well as input noise. Cathode-lead-inductance loading does, however, affect the input bandwidth.

Tube loading due to transit time is, on the other hand, of utmost importance in noise-factor considerations because it is found to have a large noise current associated with it. For transit angles less than one radian, corresponding to frequencies less than about 200 Mc. for a

[9] F. V. Hunt and R. W. Hickman, "On electronic voltage stabilizers," *Rev. Sci. Instr.*, vol. 10, pp. 6–21; January, 1941. The low-noise property that forms the feature of the present circuit is, however, entirely unconnected with the original use of the cascode as a d.c. amplifier in a voltage stabilizer.

[10] Results obtained in 1944 with the type 7F8 were variable and disappointing, but this may have been a vicissitude of early 7F8 production.

[11] E. W. Herold, "An analysis of the signal-to-noise ratio of ultra-high-frequency receivers," *RCA Rev.*, vol. 6, pp. 302–331; January, 1942.

[12] The equivalent resistance r_{eq} of the tube itself neglects i_{nr} and is defined by $r_{eq}=(i_{ns}/g_m)^2/4kTB$ (cf. (3)); it is related to R_{eq} by $R_{eq}=r_{eq}+[1/(g_m^2R_L)]$, and because the bracketed term is usually negligible, R_{eq} and r_{eq} are usually very closely equal.

[13] M. J. O. Strutt and A. Van der Ziel, "Methods for the compensation of the effects of shot noise in tubes and associated circuits," *Physica*, vol. 8, pp. 1–22; January, 1941.

tube such as the 6AK5, it has been observed[14,15] that the effects of electron-transit time can be represented by a shunt resistance R_t from grid to cathode in parallel with a noise current i_t such that

(a) the ratio T_t of $\overline{i_t^2}$ to $4kB/R_t$ is constant, that is, independent of frequency, and

(b) $$T_t \approx 5T. \tag{4}$$

This representation assumes that transit-time grid noise is statistically independent of plate noise, or, in any event, that their effects add in the mean square. For large transit angles, this assumption is incorrect.[16]

By careful design, the third source of input loading, circuit losses, can be kept small enough to have negligible effect on amplifier noise factor compared to transit-time loading, except possibly at very low frequencies where the noise factor is extremely good in any case. For example, the transit-time loading for a 6AK5 at 30 Mc. is about 15 μmho. Because of its high effective temperature, the effect on noise factor of the transit-time loading completely dominates that of circuit losses even if circuit losses introduce equal loading, corresponding to an input coil Q of about 120, which is very moderate. At higher frequencies, the coil Q required to make coil losses negligible is even smaller.

In the following discussion of noise performance, therefore, the grid loading can be assumed to consist of transit-time loading only, and i_g to be equal to i_t.

The noise factor of the circuit of Fig. 2 is

$$F = 1 + \frac{\overline{i_g^2}}{\overline{i_s^2}} + \frac{\overline{i_p^2}}{\overline{i_s^2}}\left(\frac{R_s + R_g}{R_sR_g}\right)^2 \frac{1}{g_m^2}$$

or

$$F = 1 + \frac{R_s}{R_g}\frac{T_g}{T} + \frac{R_{eq}}{R_s}\left(\frac{R_s + R_g}{R_g}\right)^2. \tag{5}$$

Because the source resistance R_s can usually be varied by suitable impedance-transforming schemes, it is desirable to determine the value of R_s that makes the noise factor of the amplifying stage a minimum. Differentiating (5) shows that this is[11]

$$R_{s,\text{opt}} = \sqrt{\frac{\overline{i_p^2}R_g^2}{\overline{i_g^2}g_m^2R_g^2 + \overline{i_p^2}}} = \sqrt{\frac{R_g^2R_{eq}}{R_g\left(\frac{T_g}{T}\right) + R_{eq}}}. \tag{6}$$

For most cases of interest,

$$\overline{i_g^2}g_m^2R_g^2 \gg \overline{i_p^2}, \tag{7}$$

which is equivalent to the condition

$$(T_g/T)R_g \gg R_{eq}. \tag{8}$$

This permits simplifying (6) to the form

$$R_{s,\text{opt}} \approx \frac{i_p}{i_g g_m} = \sqrt{R_{eq}\frac{R_g}{T_g/T}}. \tag{9}$$

Equation (9) shows that the optimum source resistance is considerably lower than the value matching the input resistance of the tube; the optimum source resistance is rather that value that makes *the plate current resulting from the grid-noise voltage equal to the plate-noise current.* For R_s approximately adjusted to its optimum value, Fig. 2 simplifies to Fig. 3.

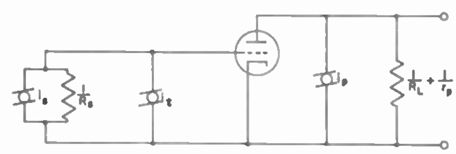


Fig. 3—Simplified equivalent circuit for band-center noise-factor analysis with R_s approximately adjusted to its optimum value, (9), so that one can neglect the transit-time loading $1/R_t$ but not the transit-time noise current i_t. Cathode-lead inductance loading and input-circuit loss are also neglected. The noise voltage at the grid, due to electron-transit time, is i_tR_s, and R_s is optimum when $g_m(i_tR_s) = i_p$.

Substituting (6) into (5) gives an expression for the optimum noise factor,

$$F_{\text{opt}} = 1 + 2\left[\frac{R_{eq}}{R_g} + \sqrt{\left(\frac{R_{eq}}{R_g}\right)^2 + \frac{T_g}{T}\frac{R_{eq}}{R_g}}\right],$$

which can be simplified under the condition of (8) to

$$F_{\text{opt}} \approx 1 + 2\sqrt{\frac{T_g}{T}\frac{R_{eq}}{R_g}}, \tag{10}$$

or

$$F_{\text{opt}} = 1 + 2\frac{R_{eq}}{R_{s,\text{opt}}}. \tag{11}$$

Because T_g/T is constant (see (4)) for the frequency range under consideration, (10) permits one to evaluate the potential noise performance of a tube without considering circuit details, but knowing only two tube properties, namely, equivalent noise resistance and input resistance due to transit time. It also indicates the manner in which optimum noise factor increases with increasing frequency. Because

$$R_g \propto 1/f^2, \tag{12}$$

it follows that

$$R_{s,\text{opt}} \propto 1/f, \tag{13}$$

and hence

$$(F_{\text{opt}} - 1) \propto f; \tag{14}$$

that is, *if as the center frequency is varied the source resistance of a grounded-cathode amplifier is continually ad-*

[14] C. J. Bakker, "Fluctuations and electron inertia," *Physica,* vol. 8, pp. 23–43; January, 1941.

[15] D. O. North and W. R. Ferris, "Fluctuations induced in vacuum-tube grids at high frequencies," PROC. I.R.E., vol. 32, pp. 419–423; July, 1941.

[16] There is some evidence, both theoretical and experimental, that the noise factor is slightly improved by tuning the input circuit somewhat below band center, about 2 Mc. at 30 Mc. and 15 Mc. at 180 Mc. The reason is the existence of a certain amount of coherence between grid and plate noise. This point is discussed in sec. 13.13 of vol. 18, "Vacuum-Tube Amplifiers," Radiation Laboratory Series, McGraw-Hill Book Co., New York, N. Y., 1948.

justed to yield the best noise factor, then the excess noise factor will be proportional to frequency.

Experimental corroboration of (14) is shown in Fig. 4, in which are displayed measured noise factors at 6, 30, and 180 Mc. (see Table 1).

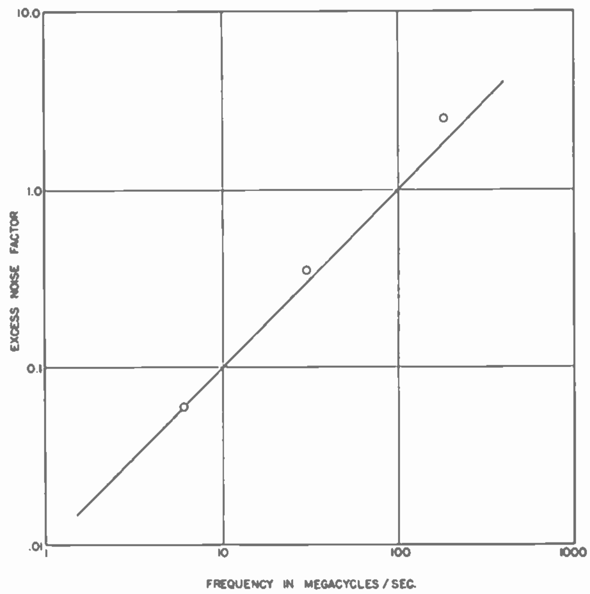


Fig. 4—Measured excess noise factors F_1 of low-noise cascode amplifiers at 6, 30, and 180 Mc. Source resistance adjusted at each frequency for optimum noise factor (see Table 1).

Although the bandwidth of the input circuit, when adjusted for optimum noise factor, does not explicitly appear in (6) and (9), it is, nevertheless, not arbitrary, but is determined for a given type of input circuit by the value of $R_{s,\,\mathrm{opt}}$ together with the tube and circuit capacitances, and is proportional to frequency (13). For many tubes having good noise performance the input-circuit bandwidth obtained by adjusting the source resistance for optimum noise factor is moderately wide. An example is the 6AK5 pentode at 30 Mc., where $R_{s,\,\mathrm{opt}} \approx 6000$ ohms and the bandwidth for a single-tuned input circuit with an input capacitance of 10 $\mu\mu$fd. is about 3 Mc., permitting an over-all bandwidth of about 1.5 Mc. Bandwidths about twice as wide can be achieved for the same transformed source resistance by using a double-tuned input circuit; if, in order to obtain even wider bandwidths, the value of R_s is reduced below $R_{s,\,\mathrm{opt}}$, the noise factor will be degraded. If, for image rejection or other reasons, it is desirable to have a narrower input bandwidth, it should be obtained by increasing the input capacitance, leaving the source resistance at its optimum value.

For the grounded-cathode amplifier of Fig. 2, the available gain is

$$G = g_m{}^2\left(\frac{R_L r_p}{R_L + r_p}\right)\frac{R_s R_g{}^2}{(R_s + R_g)^2}\cdot \qquad (15)$$

The various equations derived in this section are subject to the assumption that the tube and circuit capacitances are tuned out. Therefore, the noise-factor expression of (5) is accurate only for the single frequency at the center of the amplifier pass band. Some discussion of how the noise factor varies over the pass band is given in Part IV. One usually finds that variations in noise factor over the pass band are small enough to be neglected in rough design calculations. The notable exception to this statement occurs in the case of the grounded-grid amplifier.

Noise Factor of 6AK5 Pentode

One of the best pentodes now available as a first-stage amplifier is the type 6AK5. For this tube, $g_m = 5000$ μmho, $1/R_t = 16\times 10^{-21} f^2$ μmho/(c.p.s.)^2, and $r_{eq} = 2500$ ohms. If the load resistor for the stage is chosen to be 2000 ohms, $R_{eq} = 2520$ ohms.[12] At 30 Mc. (9) shows, taking $R_g = R_t$, that

$$R_{s,\mathrm{opt}} = 5900 \text{ ohms.} \qquad (16)$$

Using the value of (16) in (11), the optimum noise factor is found to be

$$F_{\mathrm{opt}} \approx 1 + 2\left(\frac{2520}{5900}\right) = 1.85, \quad \text{or} \quad 2.7 \text{ db.} \qquad (17)$$

Although the noise factor of (17) was derived for band center, it is in fairly close agreement with measured integrated noise factors of 6-Mc.-wide amplifiers at 30 Mc. using 6AK5 pentodes; these averaged about 3.2 db.

For the 2000-ohm load resistor, the available gain (15) is

$$G \approx (5000)^2 \times 10^{-12}(2000)(5900) \approx 300. \qquad (18)$$

The gain given by (18) is so high that even a second-stage noise factor of 10 times will not appreciably degrade the over-all noise factor of the amplifier.

Noise Factor of Hypothetical Triode

Let us now consider the performance that could be achieved if it were possible to operate the same 6AK5 tube as first stage of the 30-Mc. amplifier, but connected as a triode. For the triode connection, $R_{eq} = 400$ ohms and $g_m = 6700$ μmho, but the transit-time loading remains unchanged. Using these data, one finds that

$$R_{s,\mathrm{opt}} = 2350 \text{ ohms,} \qquad (19)$$

$$F_{\mathrm{opt}} = 1.35, \quad \text{or} \quad 1.3 \text{ db,} \qquad (20)$$

$$G = 137. \qquad (21)$$

Comparing these values with those calculated for the pentode connection (16), (17), and (18), we see that the noise factor is substantially improved. Moreover, the optimum source resistance is appreciably lowered; this permits wider input bandwidths at the optimum noise factor. The available gain remains high enough to render negligible the noise contribution of all but the noisiest second stage.

The difficulty with this plan lies in the fact that a triode-connected 6AK5 operated at 30 Mc. with the indicated source and load resistances would oscillate, and thus would be valueless.

It will be shown, however, that, through suitable connection of two triode tubes, it is possible to achieve the stability of a single pentode stage. Furthermore, the noise factor, optimum source resistance, and available gain of this combination are determined almost entirely by the first triode alone. In particular, if a triode-connected 6AK5 is used for first tube, the values given in (19), (20), and (21) can be achieved.

III. The Cascode Low-Noise Circuit—Qualitative Explanation

In preparation for the precise discussion of the cascode low-noise circuit contained in Part IV, a qualitative exposition will now be given. This discussion is restricted to band center.

Referring to Fig. 1, let g_{m1}, r_{p1}, g_{m2}, r_{p2} be the transconductance and plate resistance of the first and second tubes, and let R_2 be the load resistance of the second tube. Assuming, for simplicity, that R_2 is considerably smaller than r_{p2}, as in wide-band amplifiers, then one knows that the input resistance of the grounded-grid stage is approximately $1/g_{m2}$; this is the resistance looking to the right at points AA' of Fig. 1.

The resistance looking to the left at AA' is r_{p1}. Typical values are about 200 ohms for $1/g_{m2}$ and 4500 ohms for r_{p1}. It is this combination of very low resistance to the right and very high resistance to the left that is the crucial characteristic of the grounded-cathode, grounded-grid combination, with regard to both stability and noise factor.

a. Stability

The amplification from the grid of tube 1 to its plate is g_{m1}/g_{m2}. If g_{m1} and g_{m2} are about equal, as is usually the case, the amplification is about unity. This low amplification makes the grounded-cathode stage stable. If g_{m2} is twice g_{m1}, say (for tube 1 a triode-connected 6AK5 and tube 2 a 6J4), the amplification of tube 1 is only one-half.

b. Amplification

For a 1-volt signal applied to the input grid, the plate current of tube 1 is g_{m1} ampere. Because this current flows through the plate circuit of tube 2, the voltage across R_2, and hence the amplification of the cascode, is approximately $g_{m1}R_2$. With regard to amplification, the cascode circuit is thus equivalent to a pentode of transconductance g_{m1}.

Observe that the amplification of the cascode does not depend on g_{m2}. The motivation for large g_{m2} is essentially only this: the larger g_{m2}, the smaller is the amplification of the grounded-cathode stage, and hence the greater the stability of the grounded-cathode stage.

The transconductance of a pentode is increased when it is connected as a triode, approximately in the ratio of cathode to plate current. For this reason, the amplification of a cascode employing a triode-connected 6AK5 as first stage is actually about a third larger than that of a single pentode 6AK5 stage.

c. Noise factor

The available gain of the first stage is

$$G_1 = \frac{\mu_1^2}{4r_{p1}} \bigg/ \frac{1}{4R_s} = \frac{\mu_1^2 R_s}{r_{p1}} \tag{22}$$

where μ_1 is the amplification factor of tube 1 and R_s is the source resistance.

The noise factor F_2 of the grounded-grid stage, regarding R_2 as part of that stage, can be shown to be

$$F_2 - 1 = \frac{T_{g2}}{T}\frac{r_{p1}}{R_{g2}} + \frac{r_{eq2}}{r_{p1}} + \frac{r_{p1}}{R_2} \tag{23}$$

where T_{g2} is the effective temperature of the second-tube grid-noise resistor R_{g2}, and r_{eq2} is the second-tube equivalent plate-noise resistance.[12] In the right side of (23) the first term represents the contribution of grid noise; the second term, plate-shot noise; and the third term, thermal-agitation noise in R_2.

Typical values, pertaining to a 6AK5–half-6J6 cascode (Fig. 7) at 30 Mc. are $\mu_1 = 30$, $R_s = 2350$ ohms, $T_g/T = 5$, $r_{p1} = 4500$ ohms, $R_{g2} = 60{,}000$ ohms, $r_{eq2} = 500$ ohms, and $R_2 = 2000$ ohms; for that case

$$G_1 = 470, \tag{24}$$

which is extremely high, and

$$F_2 - 1 = 0.38 + 0.11 + 2.25 = 2.74. \tag{25}$$

Equations (1), (24), and (25) show that, in this typical case, the noise factor F_{12} of the cascode is

$$F_{12} = F_1 + 0.01. \tag{26}$$

In the same typical case, F_1 is about 1.35. Equation (26) thus validates the assertion that the noise factor of the cascode is extremely close to that of the grounded-cathode stage alone.

It follows that, although the grounded-cathode tube type should be chosen for low noise factor, noise performance is irrelevant in the choice of tube type for the grounded-grid stage.

d. Available Gain

The available gain G_{12} of the cascode, regarding R_2 as part of it, is that of a pentode of transconductance g_{m1}, source resistance R_s, and load resistance R_2; i.e.,

$$G_{12} = \frac{(g_{m1}R_2)^2}{4R_2} \bigg/ \frac{1}{4R_s} = g_{m1}^2 R_s R_2. \tag{27}$$

In the typical case above, $G_{12} \approx 200$; this is enough to make any usual third-stage noise negligible.

IV. Single-Frequency Noise Factor of the Cascode

For small-signal analysis, the low-noise cascode can be replaced by the equivalent circuit of Fig. 5, where

Y_{gp1} = grid-to-plate admittance of tube 1

$$= j\omega_0 C_{gp1}\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)$$

C_{gp1} = grid-to-plate capacitance of tube 1

f_0 = band-center frequency $= \omega_0/2\pi$

Y_{gc1} = grid-to-cathode admittance of tube 1

$$= g_s + j\omega_0 C_{gc1}\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)$$

C_{gc1} = grid-to-cathode capacitance of tube 1

g_s = transformed signal conductance at grid of tube 1

Y_{inter} = interstage admittance

$$= \frac{1}{r_{p1}} + j\omega_0(C_{pc1} + C_{gc2})\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)$$

C_{pc1} = plate-to-cathode capacitance of tube 1

C_{gc2} = grid-to-cathode capacitance of tube 2

r_{p1} = plate resistance of tube 1

Y_{pc2} = plate-to-cathode admittance of tube 2

$$= \frac{1}{r_{p2}} + j\omega_0 C_{pc2}$$

C_{pc2} = plate-to-cathode capacitance of tube 2

r_{p2} = plate resistance of tube 2

Y_{gp2} = grid-to-plate admittance of tube 2

$$= \frac{1}{R_L} + j\omega_0 C_{gp2}\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)$$

C_{gp2} = grid-to-plate capacitance of tube 2

R_L = load resistor of second stage of cascode

$\overline{i_s^2}$ = mean-squared thermal-noise current $4kTBg_s$ of g_s

$\overline{i_{n1}^2}$ = grid-noise current of tube 1

$\overline{i_{n2}^2}$ = shot-noise current of tube 1 $= 4kTBr_{eq1}g_{m1}^2$

$\overline{i_{n3}^2}$ = shot-noise current of tube 2 $= 4kTBr_{eq2}g_{m2}^2$

In analyzing the cascode by the equivalent circuit of Fig. 5, a number of approximations are made:

(a) The grid-noise current of tube 2 is neglected compared with the plate-noise current of tube 1. These two currents flow between the same two terminals and can thus be compared directly.

(b) The admittance of the grid loading of tube 1 is neglected, but the noise current associated with this loading is not.

(c) All tube and circuit capacitances with the exception of C_{pc2} are assumed to be tuned to parallel resonance by suitable parallel inductances.

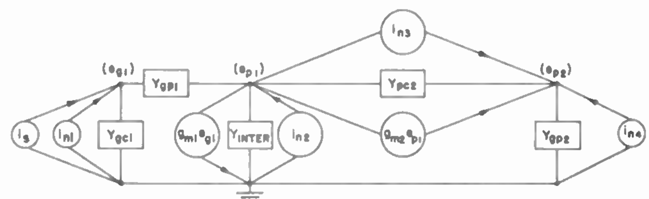


Fig. 5—Equivalent circuit for cascode noise-factor analysis.

(d) The losses associated with these inductances are assumed to be negligible, with regard to both loading and thermal noise.

(e) The grid-noise current of each tube is statistically independent of its plate-noise current.

Assumptions (a) and (e) are observed to hold for most receiving tubes at frequencies below 200 Mc. Assumption (b) is justified for most tubes by (7). Assumption (c) means that the input, interstage, and output circuits are single-tuned, and the grid-plate capacitance of tube 1 is neutralized at band center. The results obtained for this case are indicative of the behavior to be expected in general and are yet simple enough to be easily manipulated. Assumption (d) is met in practice provided care is taken to employ reasonably high-Q coils.

The node equations for the cascode equivalent circuit, written in matrix form, are

$$\begin{bmatrix} i_s + i_{n1} \\ i_{n2} - i_{n3} \\ i_{n3} + i_{n4} \end{bmatrix} = \begin{bmatrix} (Y_{gc1} + Y_{gp1}) & -Y_{gp1} & 0 \\ (g_{m1} - Y_{gp1}) & (g_{m2} + Y_{gp1} + Y_{\text{inter}} + Y_{pc2}) & -Y_{pc2} \\ 0 & -(g_{m2} + Y_{pc2}) & (Y_{pc2} + Y_{gp2}) \end{bmatrix} \times \begin{bmatrix} e_{g1} \\ e_{p1} \\ e_{p2} \end{bmatrix}. \tag{28}$$

$\overline{i_{n4}^2}$ = thermal-noise current of load resistor $= 4kTB/R_L$

T = absolute room temperature

T_g = effective absolute temperature of grid loading $= \overline{i_g^2}R_g/4kB$

B = noise bandwidth

k = Maxwell-Boltzmann constant

r_{eq1} = equivalent noise resistance of tube 1

r_{eq2} = equivalent noise resistance of tube 2

g_{m1} = transconductance of tube 1

g_{m2} = transconductance of tube 2.

We define

e_{p2n} = output voltage with all currents applied

e_{p2o} = output voltage with the noise currents i_{n1}, i_{n2}, i_{n3}, and i_{n4} set equal to zero.

Then the noise factor of the cascode circuit is

$$F = \frac{\overline{e_{p2n}^2}}{e_{p2o}^2}. \tag{29}$$

The voltage e_{p2n} is

$$e_{p2n} = \frac{\begin{vmatrix} (Y_{gc1} + Y_{gp1}) & -Y_{gp1} & (i_s + i_{n1}) \\ (g_{m1} - Y_{gp1}) & (g_{m2} + Y_{gp1} + Y_{\text{inter}} + Y_{pc2}) & (i_{n2} - i_{n3}) \\ 0 & -(g_{m2} + Y_{pc2}) & (i_{n3} + i_{n4}) \end{vmatrix}}{|Y|} \tag{30}$$

where

$$|Y| = \begin{vmatrix} (Y_{gc1} + Y_{gp1}) & -Y_{gp1} & 0 \\ (g_{m1} - Y_{gp1}) & (g_{m2} + Y_{gp1} + Y_{\text{inter}} + Y_{pc2}) & -Y_{pc2} \\ 0 & -(g_{m2} + Y_{pc2}) & (Y_{pc2} + Y_{gp2}) \end{vmatrix} \tag{31}$$

and

$$e_{p2o} = -\frac{i_s(g_{m1} - Y_{gp1})(g_{m2} + Y_{pc2})}{|Y|}. \tag{32}$$

Usually,

$$g_{m1} \gg Y_{gp1}, \tag{33}$$

$$g_{m2} \gg Y_{pc2} + Y_{\text{inter}} + Y_{gp1}. \tag{34}$$

Then, from (30) and (32),

$$\frac{e_{p2n}}{e_{p2o}} = \frac{\begin{vmatrix} (Y_{gc1}+Y_{gp1}) & -Y_{gp1} & (i_s+i_{n1}) \\ g_{m1} & (Y_{gp1} + Y_{\text{inter}}) & (i_{n2}+i_{n4}) \\ 0 & -g_{m2} & (i_{n3}+i_{n4}) \end{vmatrix}}{-i_s g_{m1} g_{m2}}, \tag{35}$$

which, when expanded, becomes

$$\frac{e_{p2n}}{r_{p2o}} = 1 + \frac{i_{n1}}{i_s} - \frac{i_{n2}}{i_s}\left[\frac{Y_{gc1}+Y_{gp1}}{g_{m1}}\right] - \frac{i_{n3}}{i_s}\left[\frac{(Y_{gc1}+Y_{gp1})(Y_{gp1}+Y_{\text{inter}})+g_{m1}Y_{gp1}}{g_{m1}g_{m2}}\right] - \frac{i_{n4}}{i_s}\left[\frac{g_{m1}Y_{gp1}+g_{m2}(Y_{gc1}+Y_{gp1})}{g_{m1}g_{m2}}\right]. \tag{36}$$

Equation (36) can be written

$$\frac{e_{p2n}}{e_{p2o}} = 1 + \frac{i_{n1}}{i_s} - \frac{i_{n2}}{i_s}\frac{g_s}{g_{m1}}[1+jQ_1\alpha] - \frac{i_{n3}}{i_s}\frac{g_s}{\mu_1 g_{m2}}[(1+jQ_1\alpha)(1+jQ_2\alpha)+jQ_3\alpha] - \frac{i_{n4}}{i_s}\frac{g_s}{g_{m1}}[1+jQ_4\alpha] \tag{37}$$

where

$$Q_1 = \frac{\omega_0(C_{gp1} + C_{gc1})}{g_s}, \tag{38}$$

$$Q_2 = \omega_0 r_{p1}(C_{gp1} + C_{gc2} + C_{pc1}), \tag{39}$$

$$Q_3 = \mu_1 \frac{\omega_0 C_{gp1}}{g_s}, \tag{40}$$

$$Q_4 = Q_1 + Q_3/(g_{m2} r_{p1}), \tag{41}$$

$$\alpha = \frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}. \tag{42}$$

In the mean square of e_{p2n}/e_{p2o}, which is the desired noise factor, all the cross products of noise currents are zero because of the incoherence[17] of the respective noise currents. After substitution of the appropriate values for the mean-squared noise currents, the single-frequency noise factor is found to be

$$F(f) = 1 + \left(\frac{T_g}{T}\right)\frac{1}{g_s R_g} + g_s R_{eq1}(1 + Q_1^2\alpha^2) + \frac{g_s R_{eq2}}{\mu_1^2}\left[(1 - Q_1Q_2\alpha^2)^2 + Q_5^2\alpha^2\right] + \frac{g_s}{g_{m1}^2 R_L}(1 + Q_4^2\alpha^2) \tag{43}$$

where

$$Q_5 = Q_1 + Q_2 + Q_3.$$

A plot of $[F(f)-1]$ for a typical 30-Mc. band-pass cascode amplifier using a 6AK5 first stage and a 6J4 second stage is given in Fig. 6. The various excess noise-factor contributions due to the two tubes and the output load resistance are also plotted. One notes that, over an 11-Mc. band, the noise contribution of the grounded-grid tube is less than the noise contribution of the output load resistor. Inspection of curves such as those of Fig. 6 shows how the integrated noise factor can be expected to deviate from the band-center value.

For the case plotted in Fig. 6, the 3-db bandwidth of the cascode circuit is about 6.5 Mc., so that at the 3-db frequencies the noise factor has increased about 0.1; if the balance of the amplifier has a bandwidth of about 7 Mc., one would expect the integrated noise factor to lie between 1.5 and 1.6 db.

If desired, the integrated noise factor can be exactly calculated, following Schremp[18]:

(a) Calculate the single-frequency noise factor $F(f)$.

(b) Calculate the transfer impedance $Z_{12}(f)$ of the cascode plus the balance of the amplifier. This is the voltage appearing at the output terminals of the amplifier when i_s is one ampere.

[17] See footnote 16.

[18] E. J. Schremp, "Vacuum-Tube Amplifiers," Radiation Laboratory Series, vol. 18, McGraw-Hill Book Co., New York, N. Y., 1948; sec. 12.7.

(c) Calculate a weighting factor $W_1^2(f)$ according to the relation

$$W_1^2(f) = \frac{Z_{12}^2(f)}{\int_0^\infty Z_{12}^2(f)df}. \qquad (44)$$

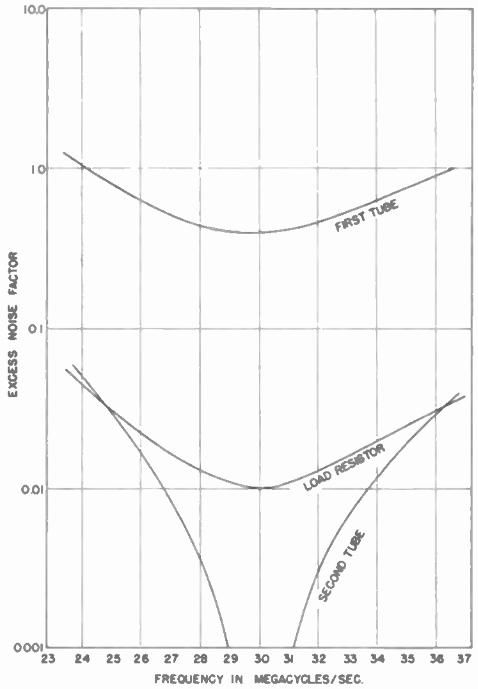


Fig. 6—Calculated single-frequency excess noise-factor components for a typical low-noise cascode. Tube data approximately those of a 6AK5-6J4 combination; source and load resistances equal to 2000 ohms.

(d) Determine the integrated noise factor from the relation

$$F = \int_0^\infty F(f)W_1^2(f)df. \qquad (45)$$

V. Practical Circuits and Experimental Results

A practical embodiment of the low-noise cascode which gives excellent results is shown in Fig. 7.

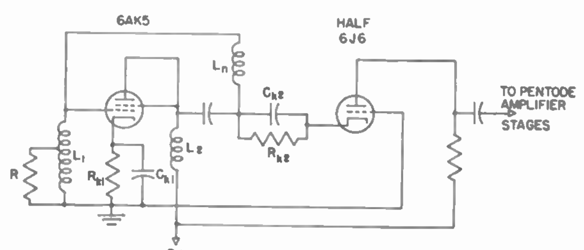


Fig. 7—Practical low-noise cascode circuit.

The grounded-cathode stage is a triode-connected[19] 6AK5. This type was found superior to the 6AG5 and 6J4 as first stage (for reasons that are not clear; there may be some connection with the fact that the 6AK5 has a gold-plated control grid, and hence small grid emission).

As the grounded-grid stage, half of a 6J6 is used, with socket pins connected as shown in Fig. 8. Strapping pins 1, 3, 5, and 6 to the center post of the socket in star fashion and grounding the combination furnishes a grounded-grid stage with a g_m of 5000 μmho and a cathode-to-plate capacitance of 0.25 $\mu\mu$fd.

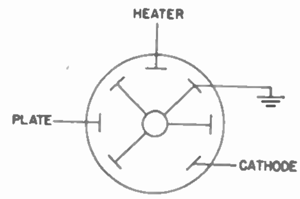


Fig. 8—Grounded-grid 6J6 socket connections.

A 6AK5 makes an unsatisfactory grounded-grid stage because the internal connection of suppressor grid-to-cathode leads to a very high cathode-to-plate capacitance, about 3.1 $\mu\mu$fd. A 6J4 is a very good grounded-grid stage but its expense is probably squandered in the cascode.

Resistors R_{k1} and R_{k2} are cathode-bias resistors of conventional magnitude, and C_{k1} and C_{k2} are their by-pass capacitors.

Coil L_1 resonates with the input-circuit capacitance at the desired band center.[16] It should be kept in mind that the input impedance of the first tube includes, by Miller effect, a capacitance $(1+A)\ C_{gp}$ in parallel with an inductance $L_n/(1+A)$, where A is the amplification of the first stage. In Fig. 7 the value of A is about unity.

The resistance R is stepped up to the value $R_{s,\,opt}$ (see Table 1) by locating the tap on L_1. If the input-circuit bandwidth so obtained is inadequate, the single-tuned input circuit can be replaced by a double-tuned circuit; this is more complicated and critical and has no advantage in noise factor, but allows about twice the bandwidth for the same impedance step-up.

The coil L_2 tunes the interstage capacitance of about 10 $\mu\mu$fd. The interstage circuit is extremely wide, about 80 Mc. in Fig. 7, because of the heavy input loading of the grounded-grid stage. For this reason, L_2 is extremely noncritical.[20]

The standing current of the grounded-grid stage flows to ground through R_{k2}, L_n, and L_1. With this arrangement, use of L_n requires no additional parts. The coil L_n tunes the grid-plate capacitance of the grounded-cathode state (1.2 $\mu\mu$fd. for the triode-connected 6AK5 of Fig. 7). It is not critical, as shown by the fact that stability is preserved if it is left out entirely, and noise factor is degraded only 0.2 db at 30 Mc. and 2.5 db at 180 Mc. However, if it is desired to adjust L_n accurately in a production prototype for resonance at band center, a signal generator can be applied to the grid terminal of

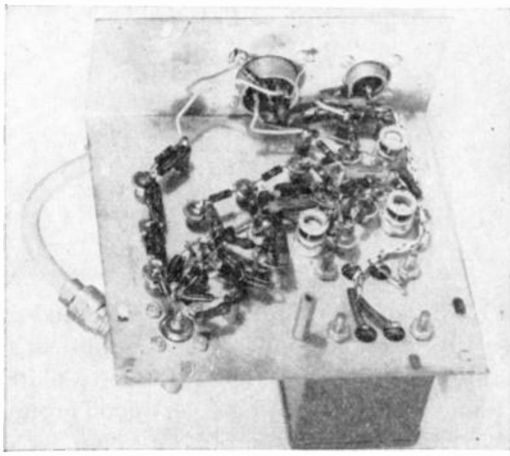
[19] Equal performance was obtained with a type 6AS6 when triode-connected by strapping grids 2 and 3 to the plate; this showed that no harm results from the grounded suppressor interposed between grid and plate of a triode-connected 6AK5.

[20] This is illustrated by the fact that, in an amplifier at 30 Mc., there was no noticeable change in noise factor, amplification, or bandwidth when the value of L_2 was inadvertently tripled.

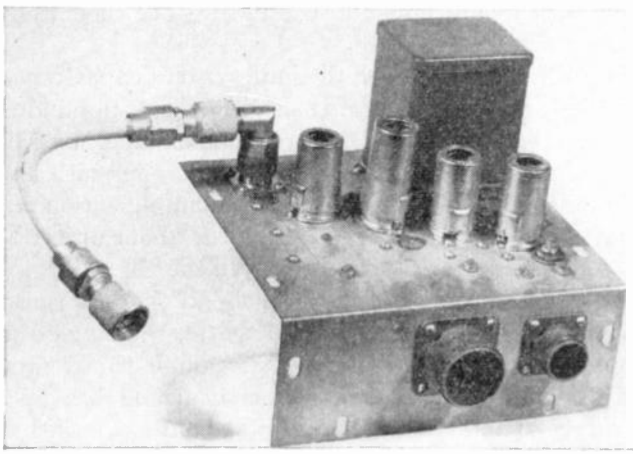
the cold[21] grounded-cathode stage and L_n proportioned for minimum transmission.

For best noise factor, L_1 and L_n should have fairly high Q's, about 200.

The photographs of Fig. 9 show a 30-Mc. amplifier consisting of a 6AK5–half-6J6 low-noise cascode followed by two 6AK5 pentode stages.



(a)



(b)

Fig. 9—Photographs of a 30-Mc. amplifier consisting of a 6AK5–half-6J6 low-noise cascode followed by two 6AK5 pentode stages. The 6AK5 of the cascode is at the left in (b).

having 100-db gains employing the cascode low-noise input circuit, at several frequencies. The noise factors were measured with noise diodes[22] and represent the integrated noise factor over the whole amplifier pass band.

The 6- and 30-Mc. amplifiers were constructed by Lawson and Nelson with every precaution to obtain least noise factor. The Q's of the input and neutralizing coils were over 200, and the 6AK5 bias was adjusted for best average noise factor ($R_{k1}=70$ ohms for 105 plate volts). Lawson and Nelson measured noise factors for 100 different 6AK5 first tubes in the 30-Mc. amplifier; the quoted 1.35-db noise factor was the median of these measurements, the range having extended from about 1.1 to 1.9 db. Changing tubes in the second stage did not affect noise factor, nor was stability affected by changes in either stage. In the 6-Mc. amplifier, there was very little variation of noise factor even with first-tube replacement.

Radar Receiver Noise Factor

By using a 30-Mc. intermediate-frequency amplifier with cascode low-noise input stage, the authors obtained, in 1945, a 3000-Mc. radar receiver with a radio-frequency noise factor F_{rf} of 7.4 ($=8.7$ db), as measured with a 3000-Mc. klystron noise source.[23] F_{rf} has the following form:

$$F_{rf} = L_{crystal} \times L_{tr} \times (F_{if} + T_{crystal} - 1) \qquad (46)$$

where $L_{crystal}$ is the conversion loss and L_{tr} is the loss in the transmit-receive switch, given as ratios, and $T_{crystal}$ is the crystal temperature index; i.e., the ratio of crystal intermediate-frequency noisiness to that of a resistor of equal intermediate-frequency resistance. In the case under discussion, $L_{crystal}$ and $T_{crystal}$ were about 3.6 and 1.1 (good values, but not the best ever obtained) and L_{tr} was about 1.4.

Newer transmit-receive switch designs permit reduction of L_{tr} to about 1.2. If the intermediate frequency were lowered to 6 Mc., as would be practical with a balanced mixer, 3000-Mc. radar receivers with noise factors of 5 ($=7$ db) could become common, even without improvement in crystal converters.

TABLE 1

NOISE FACTORS OF AMPLIFIERS HAVING LOW-NOISE CASCODE FIRST STAGE

Band center, Mc.	Over-all noise factor		$R_{s,\ opt.}$ ohms	Bandwidth, Mc.		Tubes used in cascode	Degradation of noise factor when L_n is omitted, db
	Ratio	db		Input circuit	Over-all		
6	1.06	0.25	15,000	2*	1	6AK5-6J4	not measured
30	1.35	1.35	2,500	12*	6	6AK5-6J4	0.2
180	3.5	5.5	400	30†	2.5	6J4-6J4	2.5

* Double-tuned.
† Single-tuned.

Results

In Table 1 are listed experimentally obtained noise factors and optimum source resistances of amplifiers

[21] Heaters disconnected.

[22] Radiation Laboratory Series, "Vacuum-Tube Amplifiers," "Measurement of Noise Figures," vol. 18, McGraw-Hill Book Co., New York, N. Y., 1948; chap. 14.

[23] M. C. Waltz and J. B. H. Kuper, M.I.T. Radiation Laboratory Report 443, September 17, 1943.

The Application of Projective Geometry to the Theory of Color Mixture*

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Summary—Consideration is first accorded to the basic problem of the mixture of two colors of given luminosities. It is shown that a simple geometric construction will enable determination of the point on the chromaticity diagram corresponding to the mixture for any values of relative luminosities of the two component colors forming the ingredients of the mixture.

The method is next expanded to consider the case of color reproduction by the three-color process using three primaries. Laws governing the amount of luminosity contributed to a color mixture by each of the three primary components are deduced and shown to be of simple type. Comparison of the results of choice of different sets of primaries are discussed and illustrated.

The performance of equiluminous primary systems, such as have been proposed for sequential color television, is examined critically. The color-fidelity limitations inherent in such a system are demonstrated and discussed.

The luminosity demands of each primary in a three-color television system are next examined, using the geometric method of analysis. For two given primary systems (those known as primaries *A* and primaries *C*, respectively), curves are shown indicating the contours of maximum luminosity demand of each primary when functioning in the reproduction of the full gamut of reproducible colors on the chromaticity diagram. It is shown that the maximum luminosity demand of any primary does not necessarily occur during the reproduction of white. As much as 41 per cent additional luminosity may be demanded of a given primary at a certain color as compared to its luminosity when reproducing white. In a television system, allowance must be made for this additional demand in the form of additional available undistorted voltage swing in the corresponding primary amplifier channel, if color distortion is to be avoided.

The possibilities of the method of geometric analysis discussed are pointed out, not only with regard to its use for purely theoretical analysis with a simple, direct, and pictorial approach, but also as the basis for a wide range of graphical design methods which should be capable of wide application.

I. Introduction

THE LAWS of colorimetry have been well established over the past fifty years. The result of this work culminated with the adoption by the International Commission on Illumination of a standard observer and a standard chromaticity diagram based on the standard observer with trichromatic vision. The laws of color mixture for such a standard observer are known, and may be found widely noted in the literature.[1,2]

It has been known for some time that the laws of color mixture could be expressed geometrically using an analogue between the light sources and appropriate corresponding weights supposedly located at the points on the chromaticity diagram corresponding to the colors being mixed. It is the purpose of this paper to develop some general theoretical considerations of a geometric nature, which are believed to represent a new analytical technique. By use of the method, it is possible to uncover general properties of color mixture which might not otherwise be apparent. Additionally, useful geometric constructions for the solution of color-mixture problems, without laborious arithmetical computation, will be presented.

II. Mixture of Two Colors of Given Luminosities

Assume that the two colors are specified by their co-ordinates on the chromaticity diagram and by their luminosities. Let the two colors then be

$$x_1 y_1 Y_1$$

$$x_2 y_2 Y_2.$$

Let them be represented on the diagram, Fig. 1, as points C_1C_2.

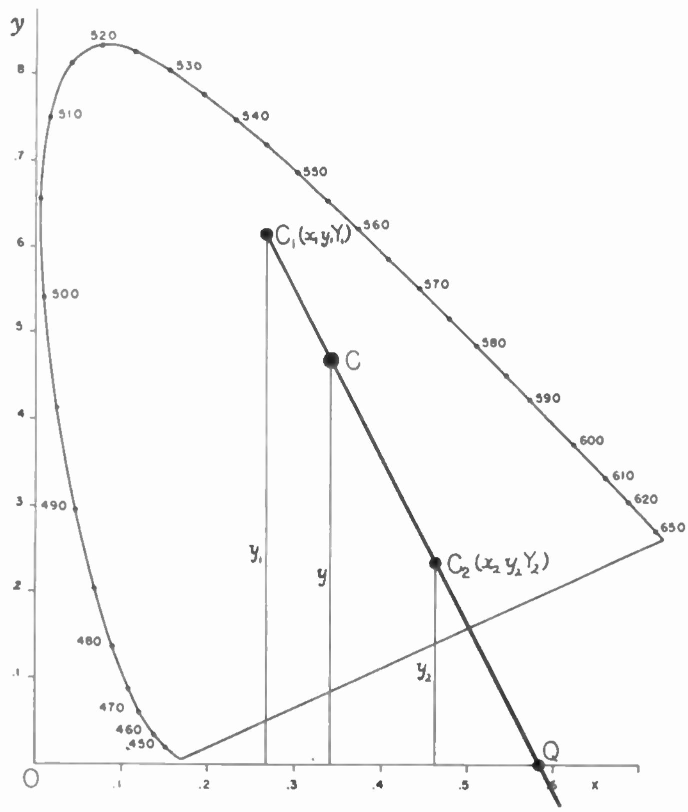

Fig. 1—Mixture of two colors.

Now we know that the point C representing the mixture will be located on the line C_1C_2 and the same loca-

* Decimal classification: R583.17. Original manuscript received by the Institute, November 5, 1947. Presented, 1948 I.R.E. National Convention, New York, N. Y., March 23, 1948.

† Philco Corporation, Philadelphia, Pa.

[1] W. D. Wright "Measurement of Color," Adam Hilger, London, 1944.

[2] A. C. Hardy, "Handbook of Colorimetry," Technology Press, Cambridge, Mass., 1936.

tion as the center of gravity of weights[1] Y_1/y_1 at C_1 and Y_2/y_2 at C_2. Further, we know that the luminosity of the mixture $Y=Y_1+Y_2$.

Let C_1C_2 intersect OX at Q. Now, regarding the two light sources being mixed as weights, we have, by taking moments about C,

$$\frac{Y_1}{y_1}\cdot C_1C = \frac{Y_2}{y_2}\cdot CC_2$$

Also, because the luminosities are additive $Y=Y_1+Y_2$. Thus we have

$$\frac{C_1C}{CC_2} = \frac{Y_2}{Y_1}\cdot\frac{y_1}{y_2}.$$

Now, from similar triangles, obviously

$$\frac{y_1}{y_2} = \frac{C_1Q}{C_2Q}.$$

Thus,

$$\frac{C_1C}{CC_2}:\frac{C_1Q}{C_2Q} = \frac{Y_2}{Y_1}.$$

If we assume the positive direction of measurement to be the direction $\overrightarrow{C_1Q}$, we can write the above equation as

$$\frac{C_1C}{C_2C}:\frac{C_1Q}{C_2Q} = -\frac{Y_2}{Y_1}.$$

Each term on the left-hand side expresses the ratio of division of C_1C_2, the first term by the point C, the second by the point Q. The division by Q is external, that by C is internal. The latter division results in a negative ratio, in accordance with the usual geometric conventions. The left-hand side may be termed a "ratio of ratios" and is known in projective geometry as the "anharmonic ratio" of the points[3] C_1C_2 C and Q. It is written (C_1C_2CQ).

We may then write

$$(C_1C_2CQ) = -\frac{Y_2}{Y_1} = -n$$

where n is the ratio of the luminosity of C_2 to that of C_1.

Now an anharmonic ratio is a projective form. If we take any point S and join it in turn by straight lines to each of the points C_1C_2CQ, the resulting bundle of rays is called a pencil, and the pencil is said to have an anharmonic ratio (C_1C_2CQ). It has the property that, if any other line is drawn to intersect the pencil in points $C_1'C_2'C'Q'$, the anharmonic ratio of these points is equal to that of the pencil; that is,

$$(C_1'C_2'C'Q') = (C_1C_2CQ).$$

Thus, from a center of projection S we have projected the four original collinear points into four new collinear points, and the anharmonic ratio has been unchanged by this projective process. Obviously, the process may be repeated indefinitely, and the anharmonic ratio will remain unchanged. Proof of this property is simple, but beyond the scope of this paper; it will be found in texts on projective geometry.[3] It is because of this property that an anharmonic ratio is called a projective form. An array of points along a straight line is referred to as a range. Thus we may say that a given pencil intersects any straight line in a range of points having the same anharmonic ratio.

It is customary to refer to the ray by lower-case letters; thus SC_1 would be referred to as the ray "c_1", SC_2 as the ray "c_2," and so on. The anharmonic ratio of the pencil is often written (c_1c_2cq). There is a general duality between points and lines which makes this convenient in certain of the theory of projective geometry.

The projective properties of anharmonic ratios can be used to enable some interesting geometric constructions to be applied to the chromaticity diagram. For example, if we wish to find the color resultant of a mixture of colors C_1 and C_2 in which the luminosity of C_2 is n times that of C_1, all we have to do is to first join C_1C_2 intersecting OX in Q and find the point C on C_1C_2 such that $(C_1C_2CQ)=-n$. This is easily done by first constructing an anharmonic pencil of this ratio, which could be made on a separate transparent or translucent sheet, and then laying it over the diagram of Fig. 1. It is then oriented so that three of the rays of the pencil pass through C_1, C_2, and Q, respectively. The intersection of the fourth ray will give the point C. Of course, in practice it is more convenient to make the original chromaticity diagram on translucent paper and lay it over the anharmonic pencil. The point C then can be directly marked on the chromaticity diagram. The principle is illustrated in the diagram of Fig. 2.

The powerful nature of the method should now be apparent. Obviously, a pencil could be constructed with fixed rays corresponding to C_1, C_2, and Q, and a number of rays corresponding to C, each one marked for a specific value of the luminosity ratio n. Thus the resultant color for any luminosity ratio can be easily determined.

III. Construction of Anharmonic Pencils of Given Ratio

To be able to effectuate the method described above, we must be able to construct suitable anharmonic pencils of any desired ratio. This can be done readily as follows: Let $ABCD$ (Fig. 3) be a range of points. Let $AC=CB$.

$$(ABCD) = \frac{AC}{BC}:\frac{AD}{BD}$$

$$= -\frac{BD}{AD}.$$

[3] J. S. Hatton, "Principles of Projective Geometry," Cambridge University Press, Cambridge, England, 1913.

Thus the anharmonic ratio is $-(BD/AD)$, and to each location of the point D will correspond a definite known value of the ratio BD/AD, and hence, also, of the anharmonic ratio $(ABCD)$.

Now take any point S and draw the rays SA, SC, SB, and SD. These rays form the desired anharmonic pencil, and any secant will cut them in a range of points having anharmonic ratio $=(ABCD)=-(BD/AD)$.

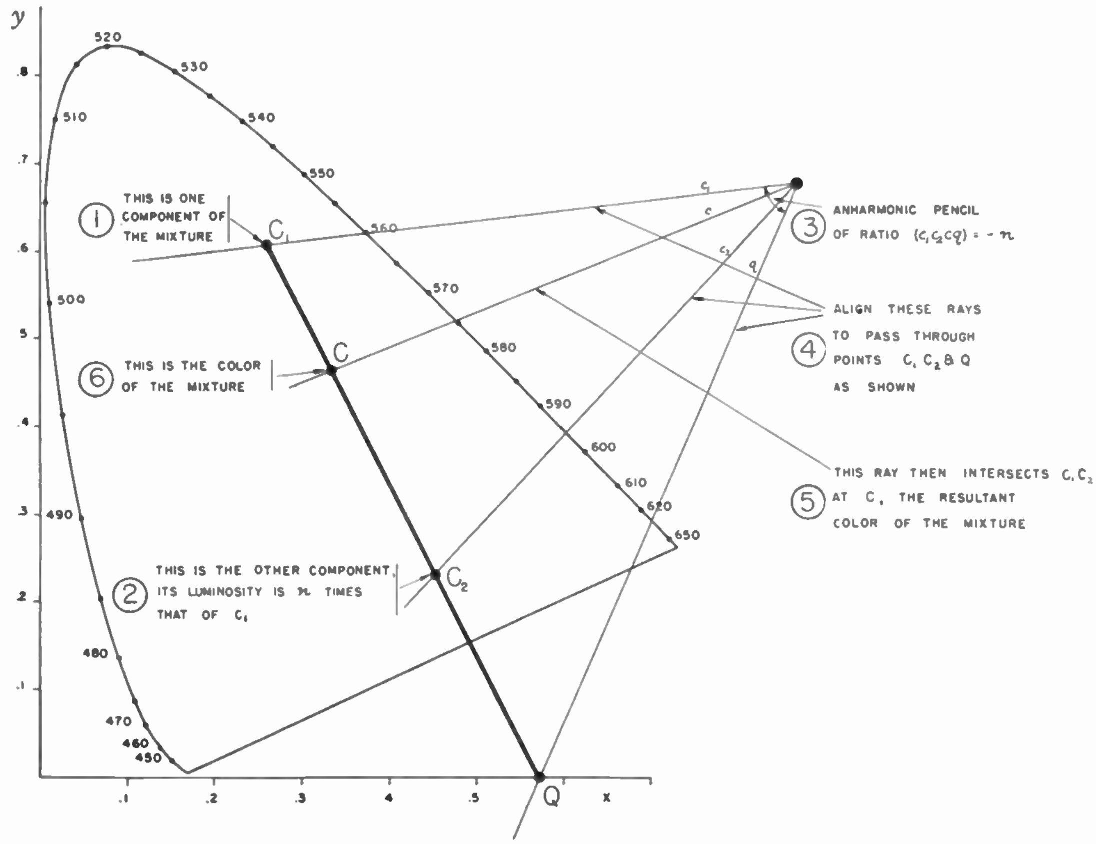

Fig. 2—Determination of the color of a mixture by means of an anharmonic pencil.

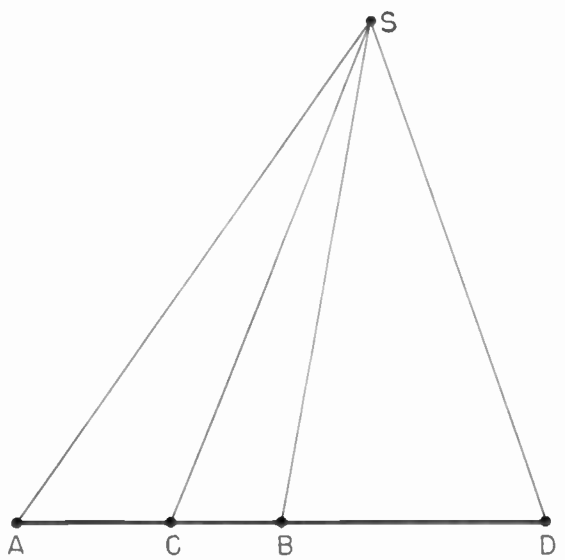

Fig. 3—Construction of an anharmonic pencil.

In drawing the pencil it is often useful to make the angles CSA and CSB equal, and perhaps of some readily measured value such as 30° or 45°. This is particularly convenient when using a drafting machine to lay out the anharmonic pencil.

The pencil, as drawn, while it can be used for the solution of mixtures of variable luminosity ratios, is not in the most convenient form for that purpose. This is because we have made d the variable ray, and this would be the one that is required to pass through point Q in Fig. 2. Obviously, it would be better for our purpose to have the rays a, b, and d fixed, since these would be required to pass through the fixed points C_1, C_2, and Q, respectively. If the ray c is made variable, it will indicate directly the resultant mixture point for various ratios of luminosities between the two component colors C_1 and C_2, with a single alignment setting. To draw such a pencil it is best to make $AB=BD$, so that

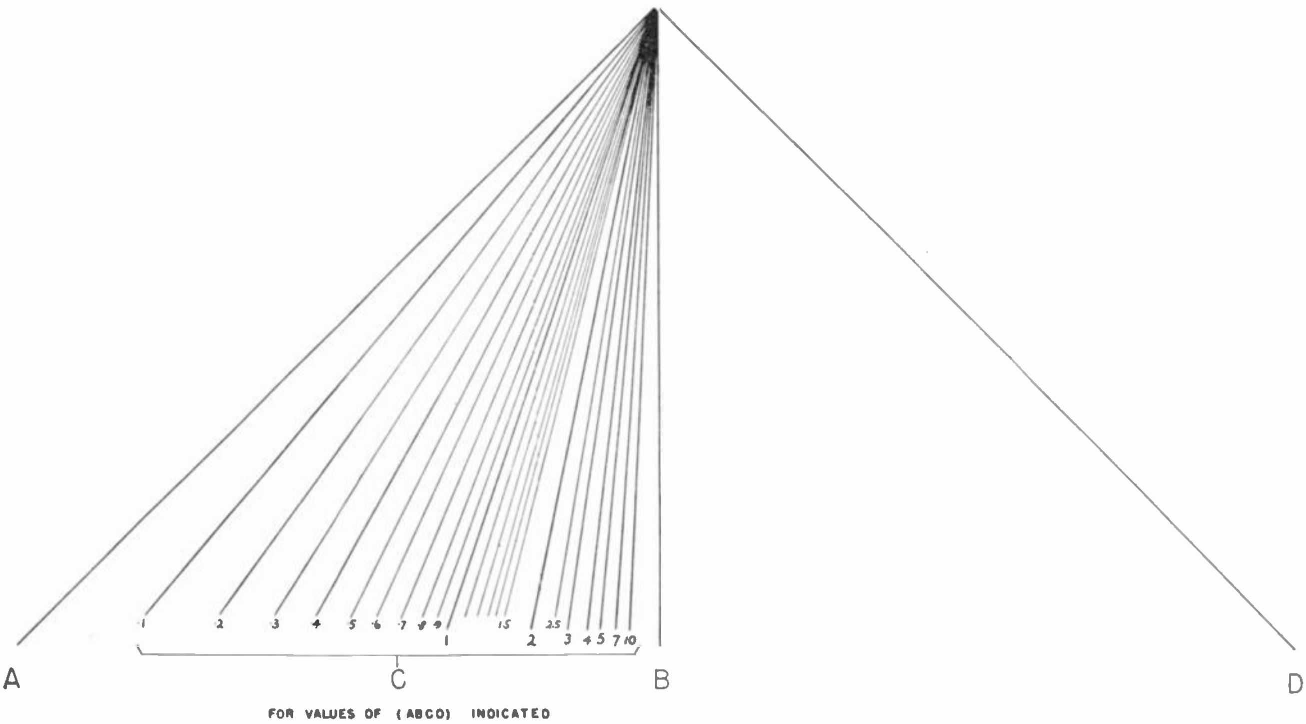

Fig. 4—An anharmonic pencil with variable ray.

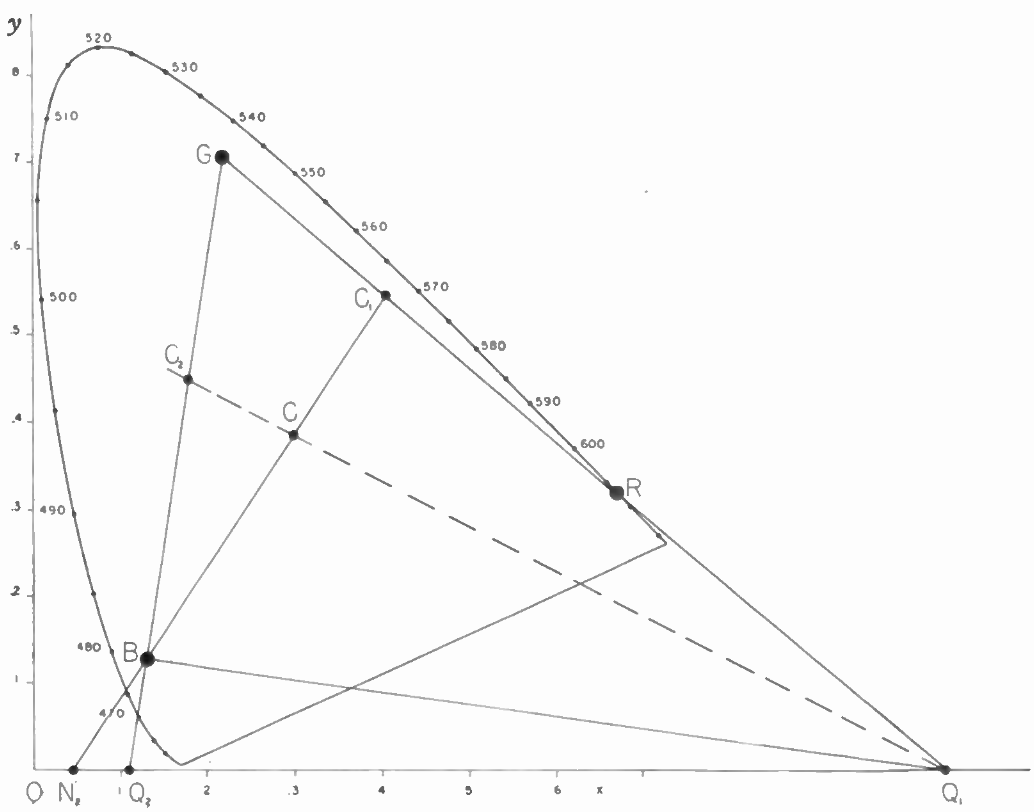

Fig. 5—Luminosity contribution of blue primary.

$AD/BD=2$ and $(ABCD)=\frac{1}{2}AC/BC$; the pencil is then easily constructed, and is shown in Fig. 4. The fixed rays are a, b, and d, while c is variable, covering a range of from $n=0.1$ to $n=10$.

IV. Application of the Method to the Theory of Three-Color Reproduction

Let us consider the subjective reproduction of colors using three primary colors, adding them in appropriate luminosities to reproduce the desired color. This technique is used in color photography and color television. It is obvious from the properties of the chromaticity diagram that a match of a given color will be possible provided the co-ordinates of the color to be reproduced lie within the triangle formed by the three primaries chosen. For this reason it is obvious that a necessary condition for wide-range color reproduction is that the triangle of primaries should encompass as large an area as possible. There are other limitations at the camera which impose further ceilings on the over-all gamut of colors that can be reproduced, but these will not be considered at this time.

Let us first consider the locus of reproduced colors to which a given primary contributes a fixed fraction of the total luminosity. We will show that this locus is a fixed straight line.

A. Locus of colors to the luminosity of which a given primary contributes a fixed fraction

Consider three primaries indicated by the points R, G, and B (red, green, and blue, respectively) on the diagram of Fig. 5. Let it be required to find the locus of colors to which the blue primary contributes a certain fixed fraction of the total luminosity. Let GR intersect OX in Q_1. Each color on the locus will be composed of certain proportions of R, G, and B. We can first combine G and R to produce a color C_1 located on the line GR. This color C_1 will have a luminosity Y_G+Y_R where Y_G and Y_R are the individual luminosities of its green and red primary components, respectively.

Now let us combine C_1 (with luminosity Y_G+Y_R) with the blue primary having luminosity Y_B. We then get a new color C lying on the line C_1B, and having luminosity $(Y_G+Y_R+Y_B)$.

Now we have a color C of luminosity $(Y_G+Y_R+Y_B)$, to which the blue primary is contributing a luminosity Y_B. That is, if the blue primary contributes a fraction f_B to the total luminosity, then

$$f_B = \frac{Y_B}{Y_G + Y_R + Y_B}.$$

Let C_1B intersect OX on the point N_2. Then the position of C on the line BC_1 is, as previously demonstrated, determined by the condition

$$(CBCN_2) = -\frac{Y_B}{Y_G + Y_R} = -\frac{f_B}{1 - f_B}.$$

For a given value of f_B, this is a constant. Now we have a pencil of rays with vertex at Q_1. There are four rays, namely Q_1G, Q_1B, Q_1O, and Q_1C. Of these four rays, the first three named are fixed in position. Hence, the fourth ray must also be fixed for a given value of f_B. Thus Q_1C is a fixed ray, and *is the locus of all colors to which the bue primary contributes a luminosity fraction* f_B.

Thus we could draw a number of straight lines through Q_1, each one corresponding to a certain fractional luminosity contribution from the blue primary. In particular, Q_1G would correspond to $f_B=0$ (no blue primary required); and Q_1B would correspond to $f_B=1$ (nothing *but* blue required).

The manner in which the family of loci can be drawn is based upon a simple extension of the principles already outlined. First, we draw an anharmonic pencil having the value $-f_B/(1-f_B)$. There can be three fixed rays and a variable ray marked with values of f_B appropriate to its positions. A pencil of this type is shown in Fig. 6. Then, by applying this pencil to the line

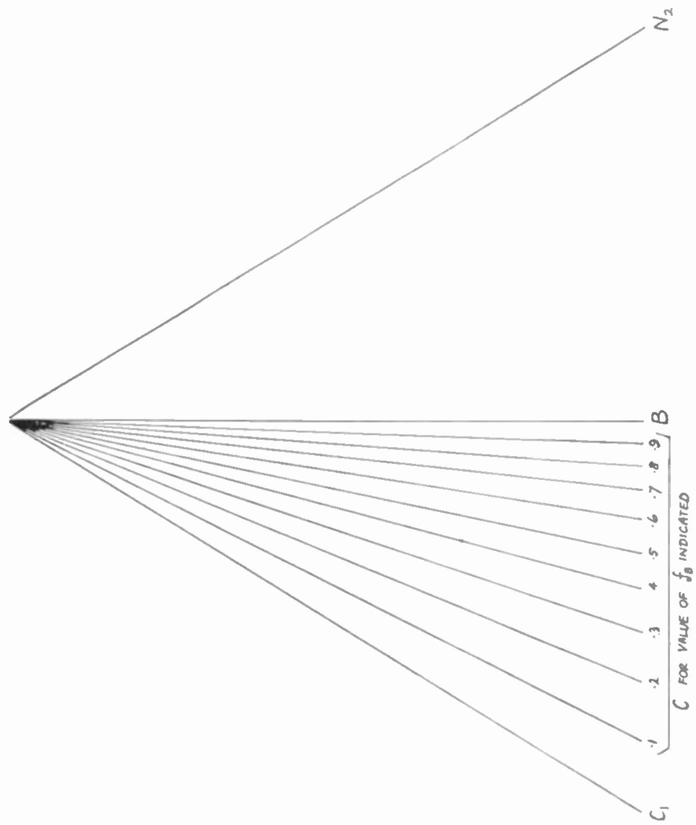

Fig. 6—Fractional luminosity pencil.

C_1N_2 and aligning appropriate rays with the points C_1,B and N_2, successive positions of C corresponding to various values of f_B can be marked off. Joining these

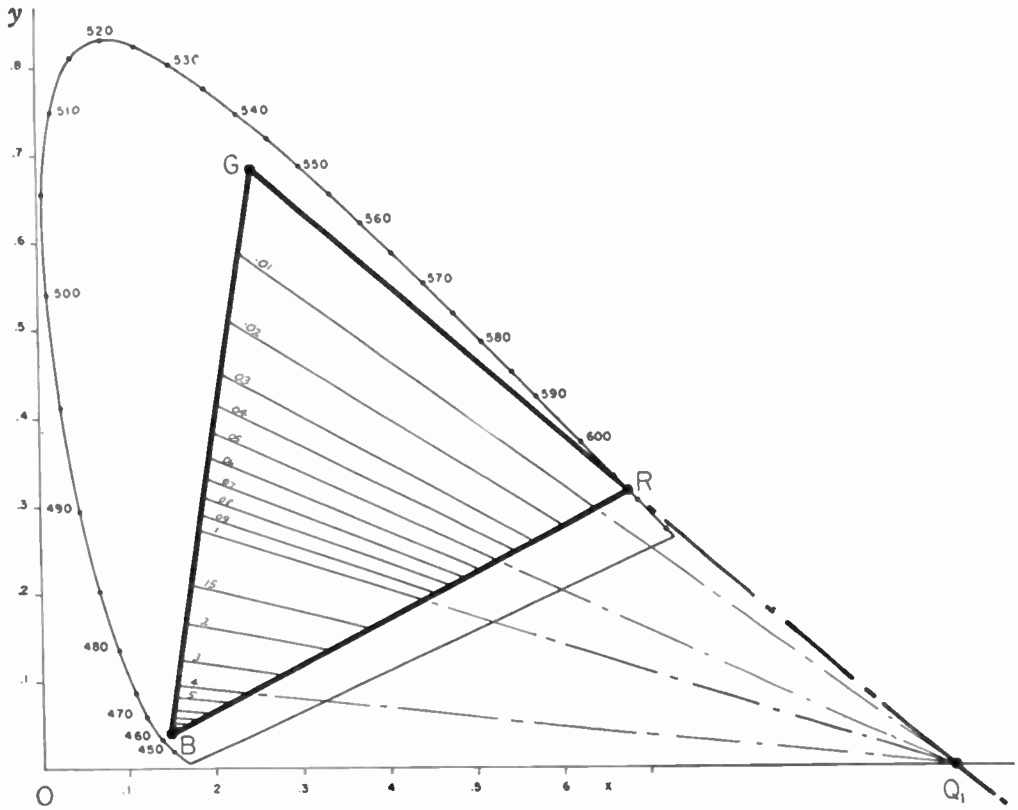

Fig. 7—Loci of constant luminosity contribution of blue primary—primaries C.

points to Q_1 gives the family of loci. This has been done and is illustrated on Fig. 7. We may note in passing that C_1 can, for the above purpose, be just as well taken to coincide with G and N_2 with Q_2, and this will incur no loss in generality. This is because, obviously $(C_1BCN_2)=(GBC_2Q_2)$, since these two ranges are projective (Fig. 5).

We may similarly consider the locus of colors to which the red primary contributes a given luminosity fraction f_R. It will be found to be a family of straight lines through Q_2 of which Q_2G will correspond to $f_R=0$ (no red needed) and Q_2R to $f_R=1$ (nothing but red needed). The other rays in the family will be determined as above for the blue. The same anharmonic pencil as used for the blue primary can also be used for the red.

Fig. 8 illustrates the loci for the red primary.

The case of the green primary is similar, but will be analyzed in detail since it requires slightly different treatment.

First we combine B and R to produce C_1 at luminosity Y_B+Y_R (see Fig. 9). Then we combine C_1 and G to produce C with luminosity $Y_B+Y_R+Y_G$. To the mixture the green primary contributes a luminosity fraction

$$f_G = \frac{Y_G}{Y_B+Y_R+Y_G}.$$

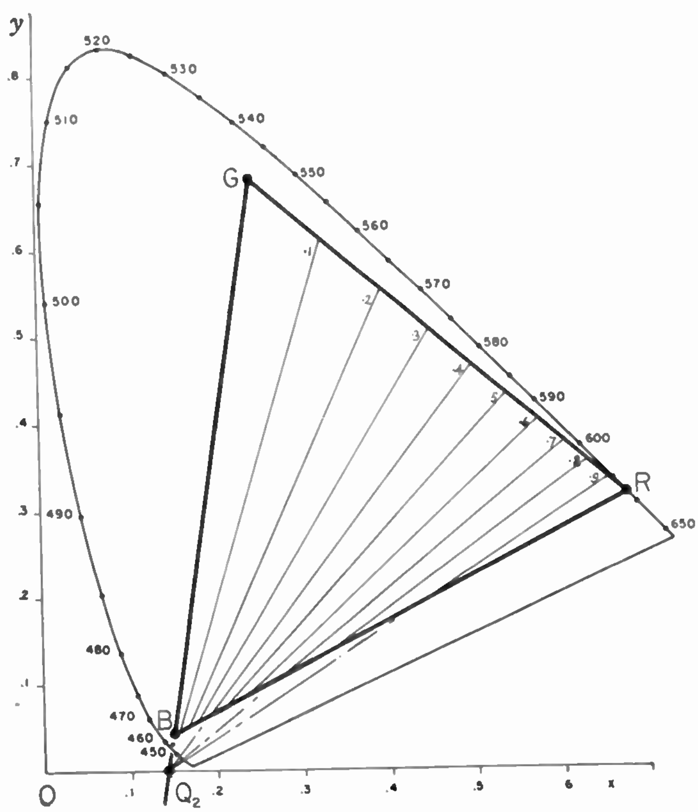

Fig. 8—Loci of constant luminosity contribution of red primary—primaries C.

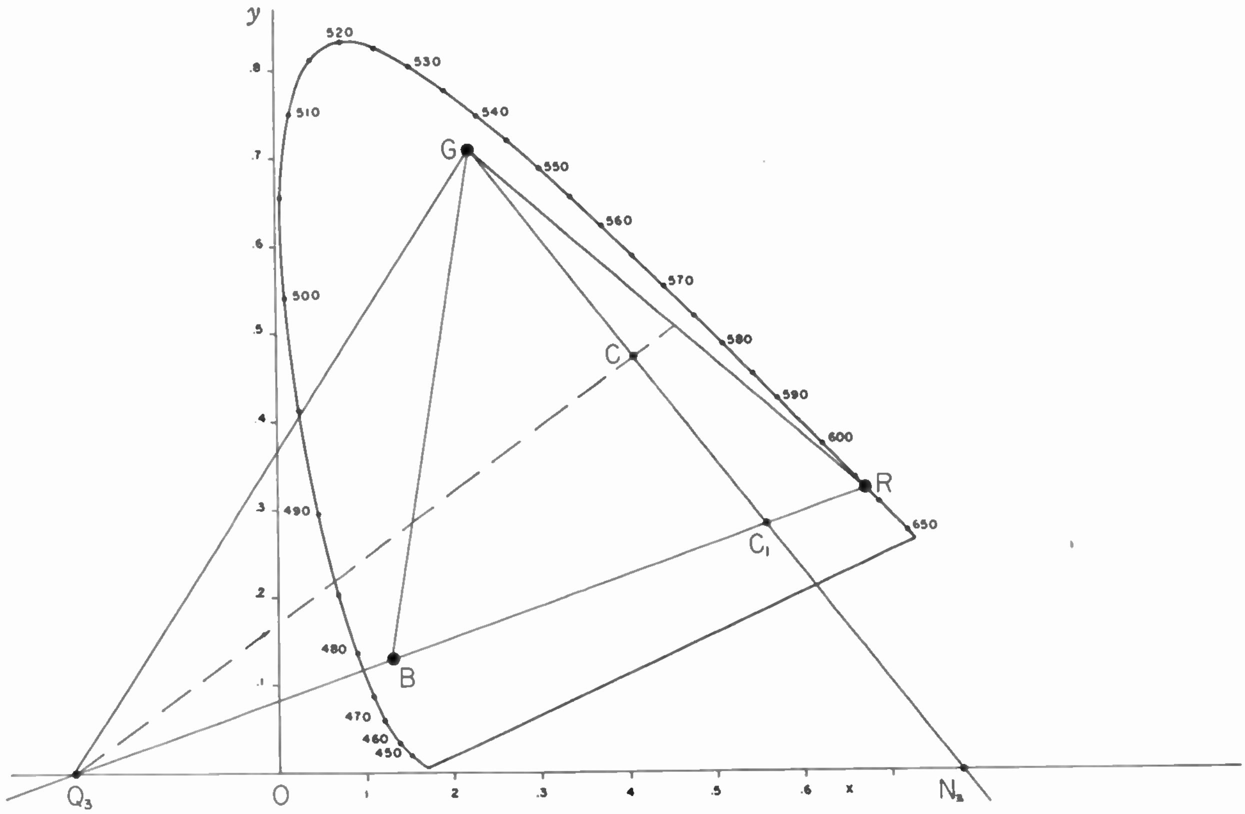

Fig. 9—Luminosity contribution of green primary.

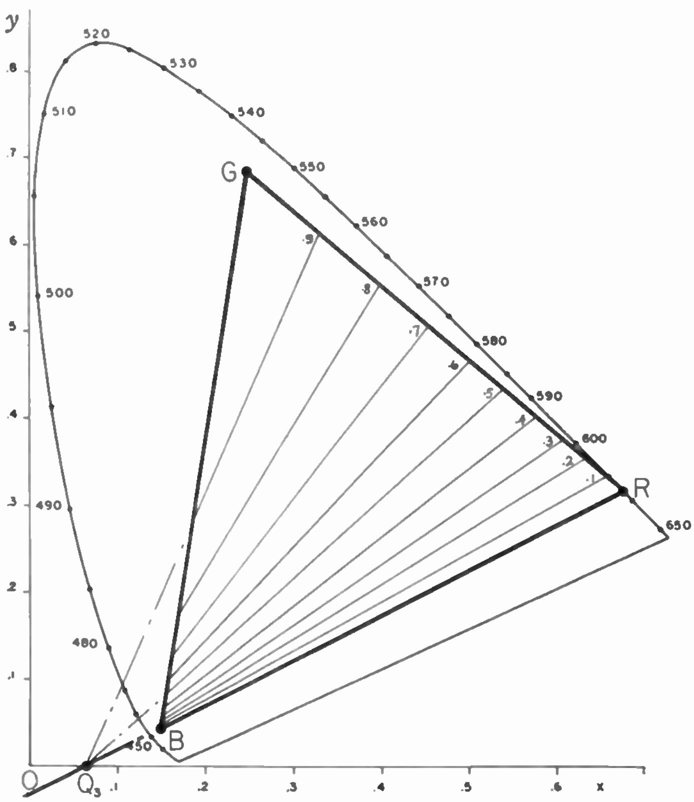

Fig. 10—Loci of constant luminosity contribution of green primary—primaries *C*.

If GC_1 intersects OX at N_3, the position of C is determined by

$$(GC_1CN_3) = -\frac{Y_B + Y_R}{Y_G}$$

$$= -\frac{1 - f_G}{f_G}.$$

Once again, the locus is a straight line.

If we now write $f_G = 1 - f$, then f is the fractional luminosity contribution of the red and blue primaries combined. Making this substitution,

$$(GC_1CN_3) = -\frac{f}{1 - f},$$

and the same anharmonic pencil that was used to determine the blue and red loci can be used here, if we remember that the parameter marked on the variable ray now represents f, or $1 - f_G$.

The resultant family of straight lines for green contribution is shown in Fig. 10. The diagram of Fig. 11 shows the three families superimposed.

It should be realized that a definite choice of primaries is implicit in the above derivation. That is to say, if primaries other than those located at R, G, and B in

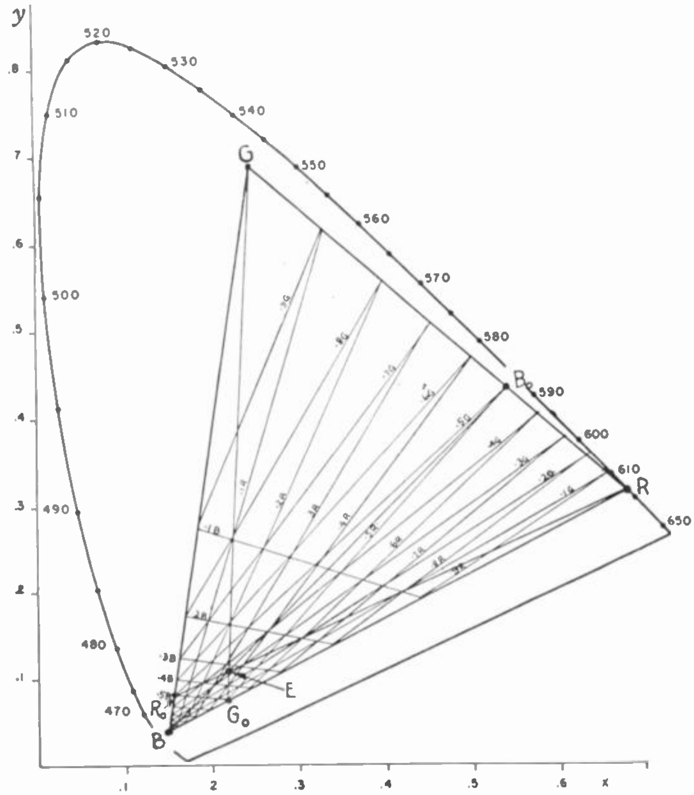

Fig. 11—Constant luminosity contribution loci superposed—primaries C.

tions of R, G, and B primary points, but also in the placement of the constant-luminosity-contribution loci. Nevertheless, these loci would be obtained from the primary locations by the same geometric process using the same fraction-of-luminosity pencil (Fig. 6) as was used previously. In other words, the method is perfectly general and will give the appropriate solution for any given set of primaries. Indeed, we will find this universal-application property very useful in comparing various performance factors resulting from a variety of possible primary choices.

The actual primaries used in Figs. 7, 8, 10, and 11 were those which have been referred to as primaries "C".[4] This set of primaries is described by the following co-ordinates:

Primary color	x	y
Red	0.6805	0.3193
Green	0.2500	0.6885
Blue	0.1477	0.0412

Another possible set of primaries is that designated in the above reference as primaries A. These cover a considerably smaller gamut of reproducible colors, but have been given some consideration in television for other reasons.

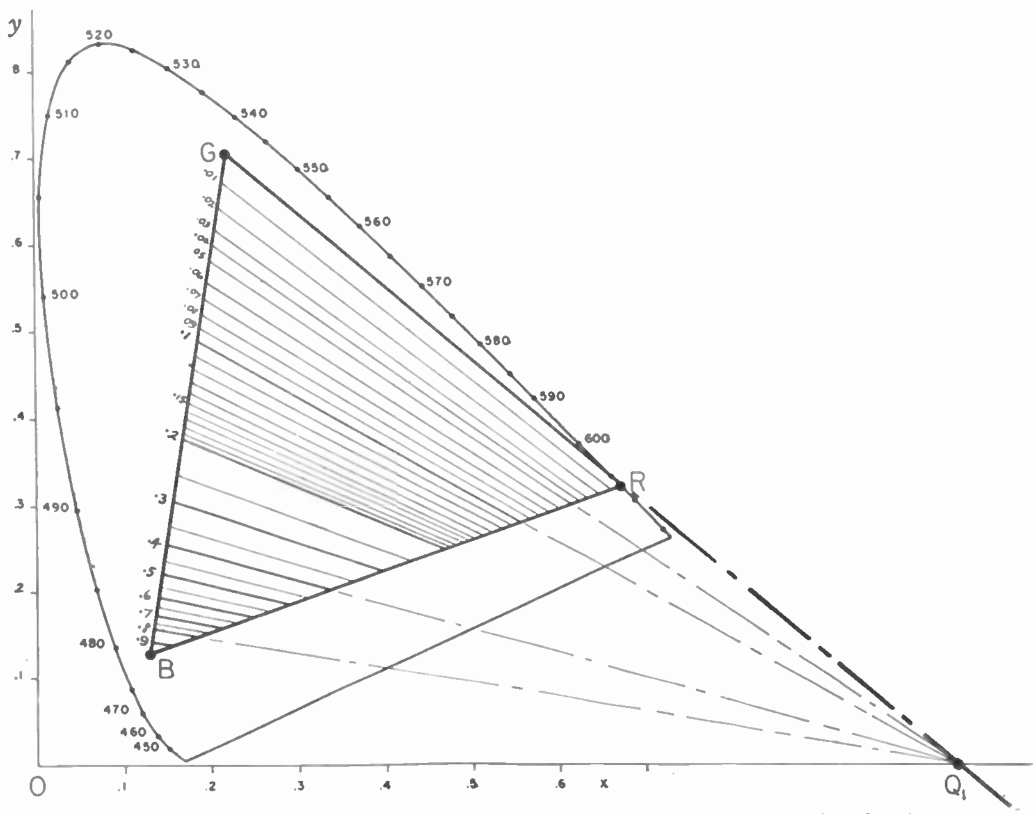

Fig. 12—Loci of constant luminosity contribution of blue primary—primaries A.

Figs. 7, 8, 10, and 11 had been chosen, the actual diagrams would have been different, not only in the loca-

[4] Report of Sub-committee on Color of Panel 6 (Television) of Radio Technical Planning Board; issued November 26, 1946, Report No. TS2.1-2144.

The corresponding co-ordinates are:

Primary color	*x*	*y*
Red	0.675	0.326
Green	0.221	0.712
Blue	0.130	0.130

The corresponding fractional-luminosity-contribution loci are shown in Figs. 12, 13, and 14, for blue, red, and green primaries respectively. They are shown superimposed in Fig. 15. It is interesting to note that in Figs. 11 and 15, at each intersection of a trinity of red, green, and blue fraction rays the sum of the luminosity contributions is unity, as of course it should be.

Referring to Figs. 11 and 15, we note that the locus of colors to which blue and red contribute equally in luminosity is a straight line through A passing through the intersections of pairs of red and green fraction rays corresponding to equal fractions. Particularly, of course, the 0.5 ray of red and blue contribution also intersect on the line BR, as they should do, since for colors on this line there is no luminosity required of the green primary. This point of intersection is marked G_0, and the locus of equal blue and red luminosity contribution is then the line GG_0. Similarly, there is a locus BB_0 for equal red and green luminosity contributions, and a locus RR_0 for equal blue and green luminosity contributions. These three lines intersect in a single point E, which of course corresponds to the color demanding equal luminosities of the three primaries. By comparing Figs. 11 and 15, the wide difference in location of the point E in the two cases is obvious.

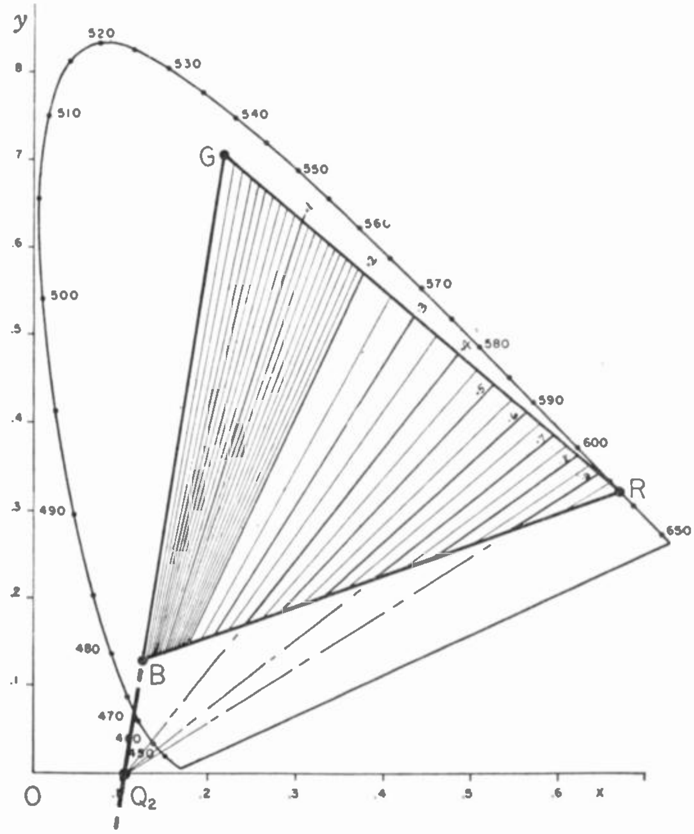

Fig. 13—Loci of constant luminosity contribution of red primary—primaries A.

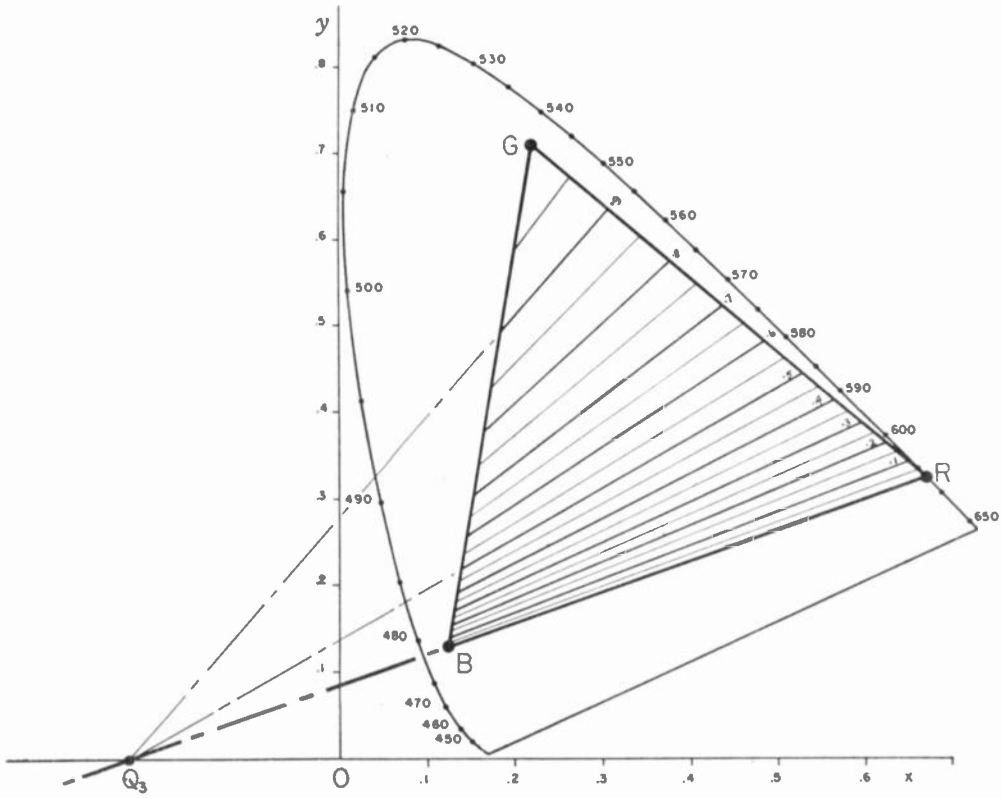

Fig. 14—Loci of constant luminosity contribution of green primary—primaries A.

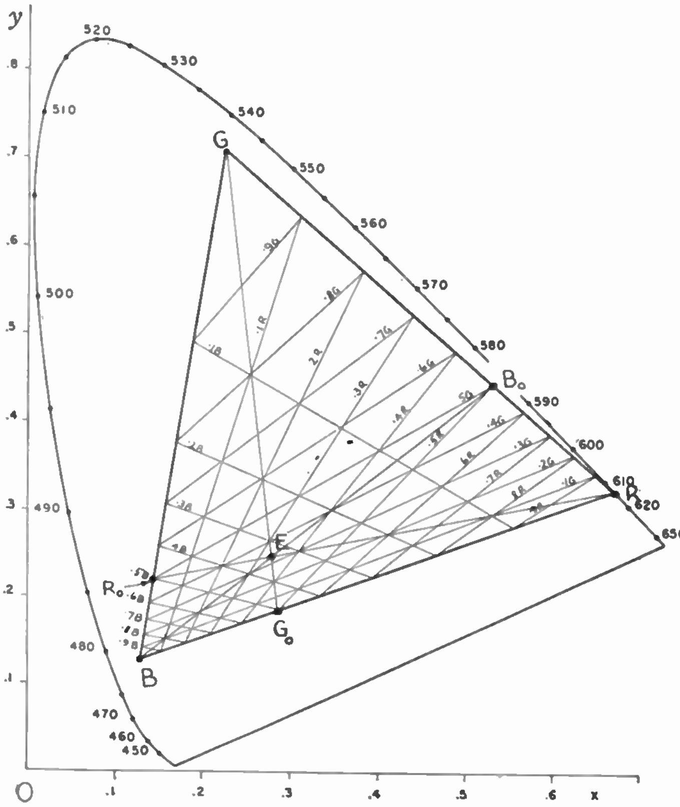

Fig. 15—Constant luminosity contribution loci superposed—primaries *A*.

It is obvious that Figs. 11 and 15 can be used to calculate the signal voltages required in the red, green, and blue channels of a color television system. It is only necessary to know the relation between channel voltage and relative receiver primary luminosity for each of the three primaries. Assuming a linear relation between channel voltage and luminosity, we will then obtain for each primary channel a factor by which the luminosity must be multiplied to obtain the voltage. The luminosity contribution loci can then be relabeled with the corresponding channel voltage, thus giving a map displaying the relation between color reproduced and the three channel voltages.

B. Equiluminous primaries

We may note that it was the difference in the equiluminous points that led to the consideration of primaries *A* for sequential color television. In this type of color television the colors are built up by successive presentation of red, green, and blue separation images. The persistence of vision is then called upon to fuse these images into a composite, colored image. The particular system under consideration was being operated above the flicker threshold, and it was hoped that, at least for white objects, the principle of having primary luminosities more nearly equal when reproducing white would raise the flicker threshold. This corresponds to having

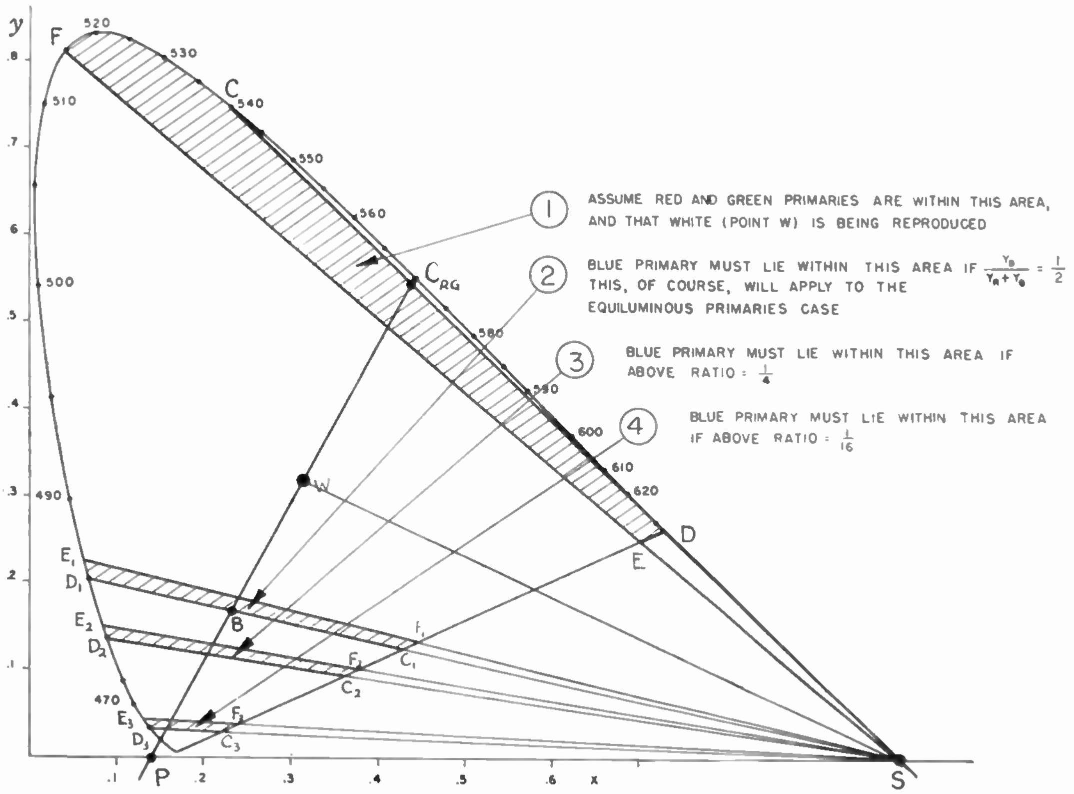

Fig. 16—Permissible locations of blue primary for various values of Y_B/Y_R+Y_G when reproducing white.

the equiluminous point E (Figs. 11 and 15) closer to white. Some increase in flicker threshold brightness was indeed noted, but the system was deficient in fidelity of color rendition, particularly in the blue. In fact, the more nearly equal the three primary luminosities are, the worse will be the color fidelity in the blue portion of the chromaticity diagram.

Why this is so can be seen by reference to Fig. 16. Here we will first consider the case of équiluminous primaries, i.e., primaries which are so chosen as to have equal luminosities when reproducing white. Initially, let us consider the red and green primaries and assume they lie on the line CD. This line certainly represents an extreme case because, while the red primary could certainly fall upon this line, the green filter would have to be very narrow so that it would have low visual efficiency. Neither primaries C or A have a green primary that is this close to the spectral locus. Nevertheless, the line CD represents an extreme that might be used, and will provide a useful starting point for the discussion.

Assuming, then, that the red and green primaries of our postulated equiluminous primary system are to be on CD, we know that their resultant will also lie on CD and will have twice the luminosity of either—let us say, then, a luminosity of $2L$. Now we have to add a blue primary, also of luminosity L, to produce white, as indicated by the point W. If C_{RG} represents the red-green resultant point, we join C_{RG} to W and let the line $C_{RG}W$ intersect OX in P. Now we have a color W which is the resultant of $2L$ at C_{RG} and L at B, where the location of B is determined as previously by the relation

$$(C_{RG}BWP) = -\tfrac{1}{2}.$$

This determines the point B.

Next we note that, if CD intersects OX in S and we join WS and BS, we have an anharmonic pencil whose ratio $= (C_{RG}BWP) = -\frac{1}{2}$ and is therefore fixed. Thus, as C_{RG} assumes various positions along the line CD, corresponding to different choices of pairs of red and green primaries, the corresponding locus of B is the fixed straight line C_1D_1.

Now let us draw another straight line FE through S, to indicate another extreme possibility along which the red and green primaries of the postulated equiluminous system might be located. This line is intended to indicate the furthest distance within the spectral locus that the red and green primaries might be located. Corresponding to this line, we find another locus E_1F_1 for the blue primary.

In order to retain physical meaning, the loci must be considered bounded by the spectral locus, since no real colors can fall outside the spectral locus. What we have just proved, then, is that, for an equiluminous primary system for which the red and green primaries lie within the area $CDEF$, the corresponding blue primary must always lie within the area $C_1D_1E_1F_1$. Furthermore, the line C_1D_1 corresponds to the locus of the most saturated blue primary that can be used, since it corresponds to red and green primaries lying on the line CD. We can now examine the available "blues" that correspond to the area $C_1D_1E_1F_1$ by listing the Wratten filters that have colors falling within this area. It will be found that filters described as "blue-green," "bluish," and "magenta" represent the only range from which blue primary filters can be chosen. Examination of these filters will show them to be unsuitable for blue reproduction.

To make the diagram more complete, areas $C_2D_2E_2F_2$ and $C_3D_3E_3F_3$ are shown. These correspond to

$$\frac{Y_B}{Y_R + Y_G} = \frac{1}{4} \quad \text{and} \quad \frac{Y_B}{Y_R + Y_G} = \frac{1}{16},$$

respectively, and represent the conditions for primaries A and C, respectively. Bearing in mind that no color lying outside the triangle of primaries can be reproduced it is obvious how much of the blue area of the diagram cannot be reproduced at all with equiluminous primaries or with primaries A. It will be seen that primaries C, however, have excellent blue reproduction.

C. Luminosity demands in a three-color reproduction system

In a color-reproduction system based on mixture of three primaries (or any number, for that matter), to reproduce colors subjectively the luminosities of the primaries will vary with the color being reproduced and its brightness. In a natural scene we have an array of colored objects and a source of illumination. The objects are viewed by the light they reflect as a result of the irradiation they receive from the illuminating source or sources. The only exceptions to this statement occur in the case of self-luminous objects, such as lamps, automobile headlights, fires, and the like. In the following discussion we will exclude consideration of such self-luminous objects.

An object which is illuminated will reflect light. To the extent that it does not reflect light of all wavelengths equally, it will appear colored. Its apparent luminosity to an observer will depend upon its coefficient of reflection through the visible spectrum, as well as upon the manner in which this coefficient varies through the spectrum. MacAdam[5] has shown that the greatest luminosity a given colored object can have occurs when (1) its reflection coefficient is unity throughout the spectral region reflected by it, and (2) it has not more than two separate reflection bands within the visible spectrum. Based upon these premises, he has demonstrated that the maximum luminosity a colored object can have under any given illuminant depends upon its color (as expressed by co-ordinates on the chromaticity diagram) and upon the illuminant. For any given illuminant we

[5] D. L. MacAdam, "Maximum visual efficiency of colored objects," *Jour. Opt. Soc. Amer.*, vol. 25, pp. 249 and 361; 1935.

can draw sets of contour lines on the chromaticity diagram connecting points representing colors whose maximum visual efficiencies have stated values. Here the term "visual efficiency" means the ratio of the luminosity of a given colored object to that which the object would have were its surface 100 per cent reflective throughout the visible spectrum. Expressed mathematically,

$$\text{visual efficiency } V_E = \frac{\int_{\lambda_1}^{\lambda_2} E r_\lambda \bar{y} d\lambda}{\int_{\lambda_1}^{\lambda_2} E \bar{y} d\lambda}$$

where E = power distribution of the illuminant as a function of wavelength, usually (but erroneously) referred to as the "energy" distribution

r_λ = reflection coefficient of the object, as a function of frequency

$\bar{y}$ = the distribution function for the I.C.I. standard observer, usually called the visibility function

λ_1, λ_2 = the two extremes of the visible spectrum.

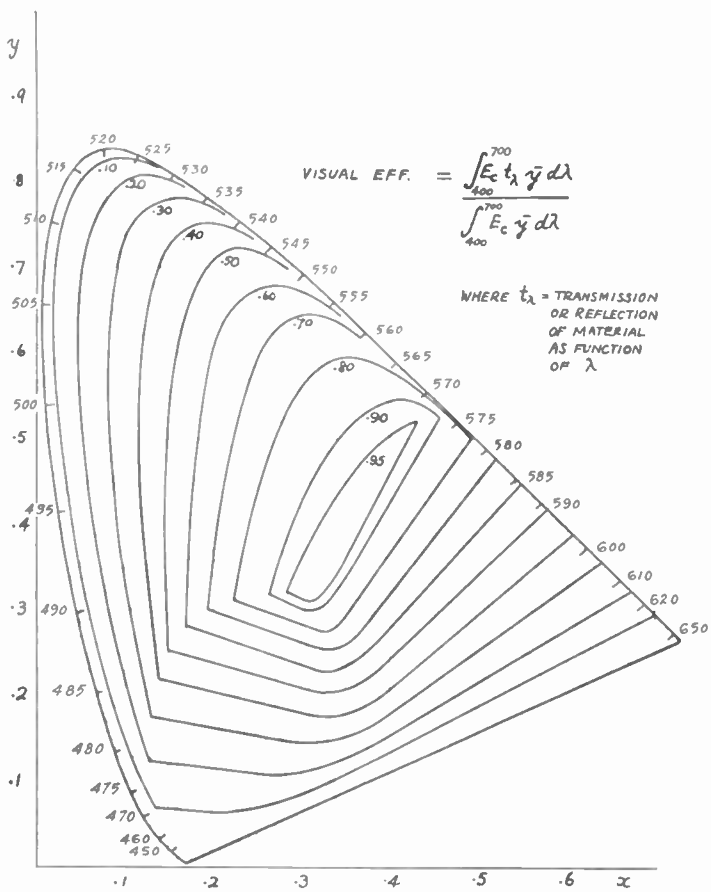

Fig. 17—Maximum possible visual efficiency of materials producing indicated chromaticities when illuminated by standard illuminant *C*.

The maximum visual efficiency would be the result of carrying out this integration when r_λ consisted of one or two reflectance bands throughout which the reflection coefficient was unity.

MacAdam[5] has carried out these various integrations and has also presented chromaticity diagrams for several standard illuminants showing contours of maximum visual efficiency. Fig. 17 is copied from his paper, and shows the contours for illuminant *C*. It will be noted that the contours inclose increasingly large areas as the maximum visual efficiency decreases, corresponding to increasingly narrow reflectance bands. The spectral locus should really be marked zero maximum visual efficiency, since it is the locus of colors comprising infinitely narrow spectral bands having, therefore, vanishingly small luminosity. Similarly, the point corresponding to the illuminant corresponds to a maximum visual efficiency of unity. Notice how the high-visual-efficiency colors are those in the red, orange, and green sections of the diagram. This is due in part to the high visual sensitivity in this region, and in part to the straightness of the spectral locus over some of this region.

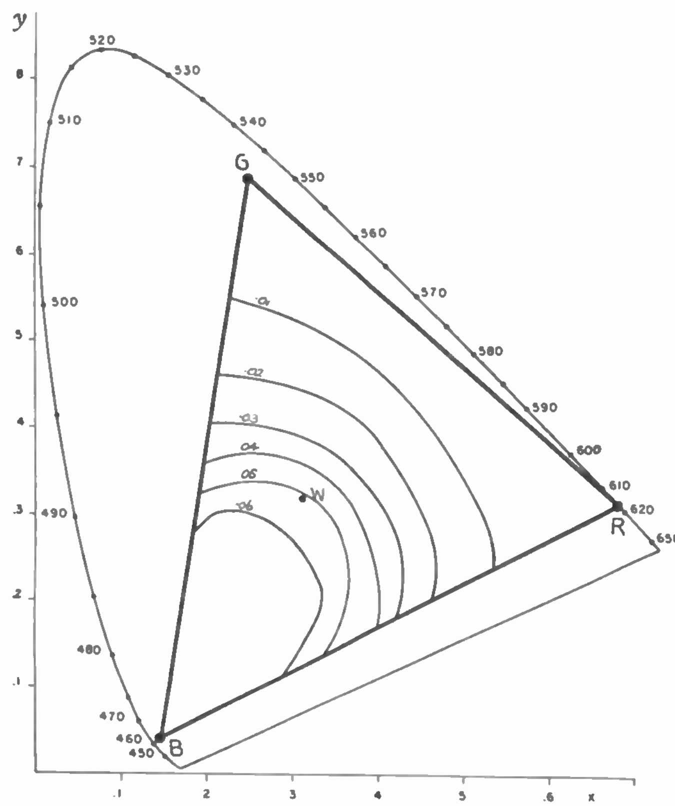

Fig. 18—Maximum luminosity demand contours of blue primary—primaries *C*.

The straightness of the spectral locus from 550 to 700 mμ allows quite wide-band-reflectance materials to exhibit colors which subjectively are the equivalent of pure spectral colors; this is particularly true in the yellow and orange red. It should also be noted how low are the visual efficiencies in the blue region.

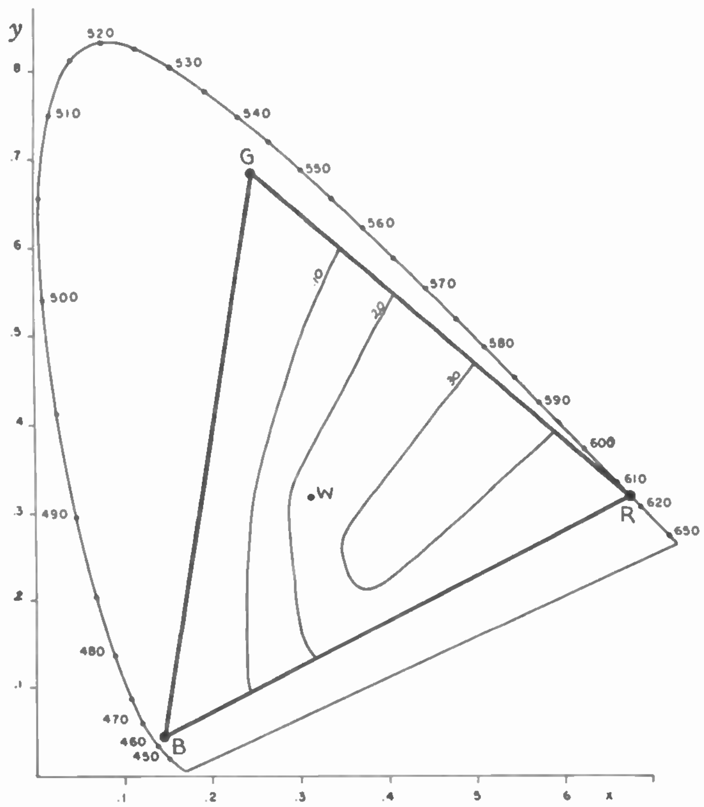

Fig. 19—Maximum luminosity demand contours of red primary—primaries C.

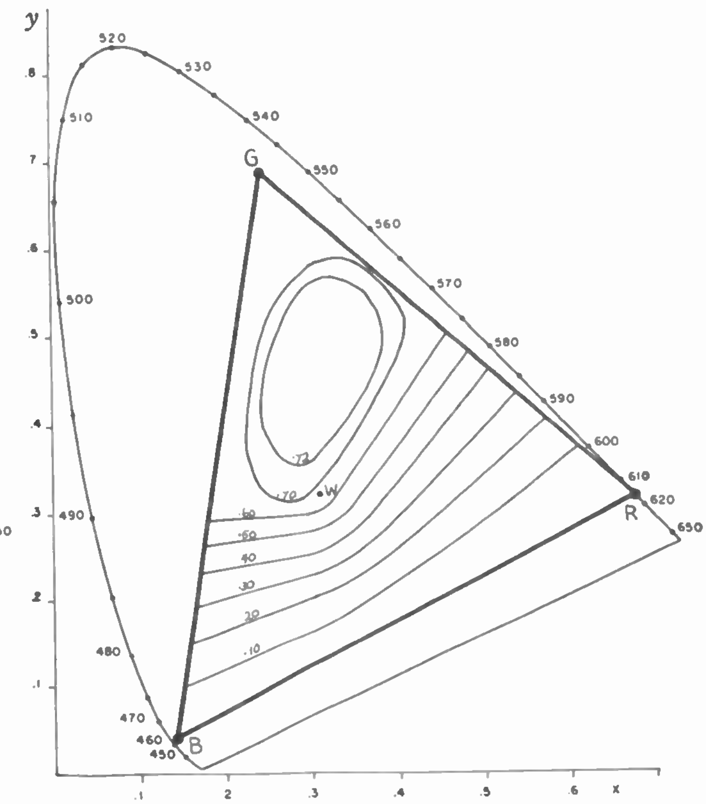

Fig. 20—Maximum luminosity demand contours of green primary—primaries C.

Now let us consider that we wish to reproduce a scene using a three-primary reproducing system. Let the scene be illuminated by illuminant C. Then, corresponding to each color that we wish to reproduce, there will be a certain maximum visual efficiency in which that color may be encountered. Thus, relative to a uniformly and completely reflecting white object, colored objects will have certain maximum possible luminosities which will have to be accurately reproduced if distortion is to be avoided. Now the luminosity of the reproduced color is the sum of the luminosities of its three primary components. We have already shown how to determine, for given primaries, what fraction of the total luminosity of a given color is contributed by each of the three primaries. By superimposing MacAdam's maximum visual efficiency contours in turn upon the luminosity-contribution loci pencils (referred to hereafter as LC pencils) for red, green, and blue primaries, we can determine at any color how much luminosity is demanded of each primary relative to the luminosity of a uniform and completely reflecting white object (hereafter referred to as a UCR white object). Thus, for example, the intersection of the 0.3 ray of the blue LC pencil with the 0.6 maximum visual efficiency will determine points corresponding to colors at which the maximum demand for luminosity of the blue primary would be $0.3 \times 0.6 = 0.18$ of the luminosity of a UCR white object.

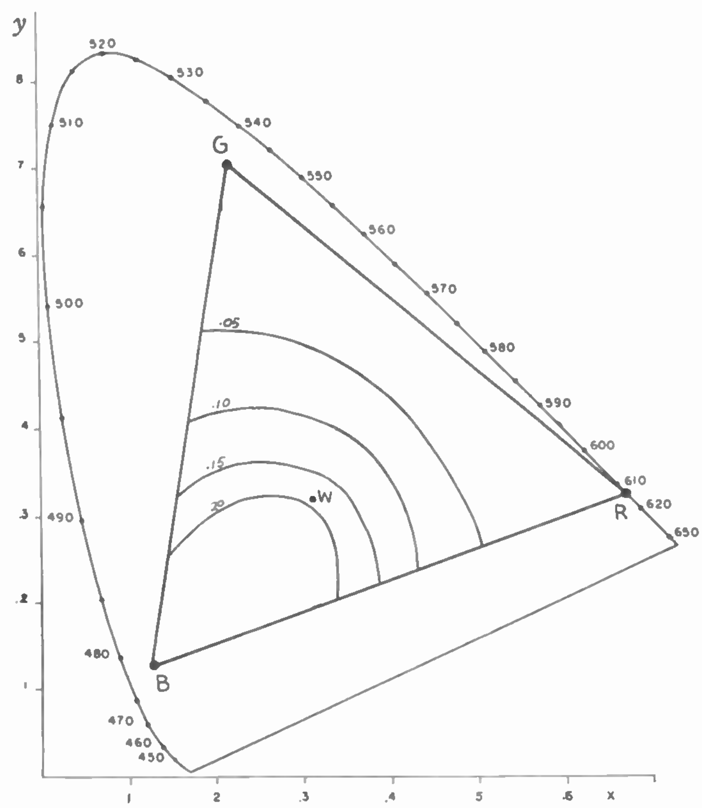

Fig. 21—Maximum luminosity demand contours of blue primary—primaries A.

By taking intersections of this kind throughout the diagram, we can draw a set of contours representing maximum demand for the blue primary. Such a set of contours for blue primaries *C* is presented in Fig. 18. Similar contours of red and green demand are shown in Figs. 19 and 20, respectively. Similar contours for primaries *A* are shown for blue, red, and green primaries, respectively, in Figs. 21, 22, and 23.

Table I shows that the additional luminosity demand can be as much as 41 per cent over that demanded for white reproduction. This condition occurs with the green primary *A*. Thus, in a color television system we must be careful not to fill the available channel amplitude characteristic when reproducing white, as overload and attendant color distortion would occur for other colors.

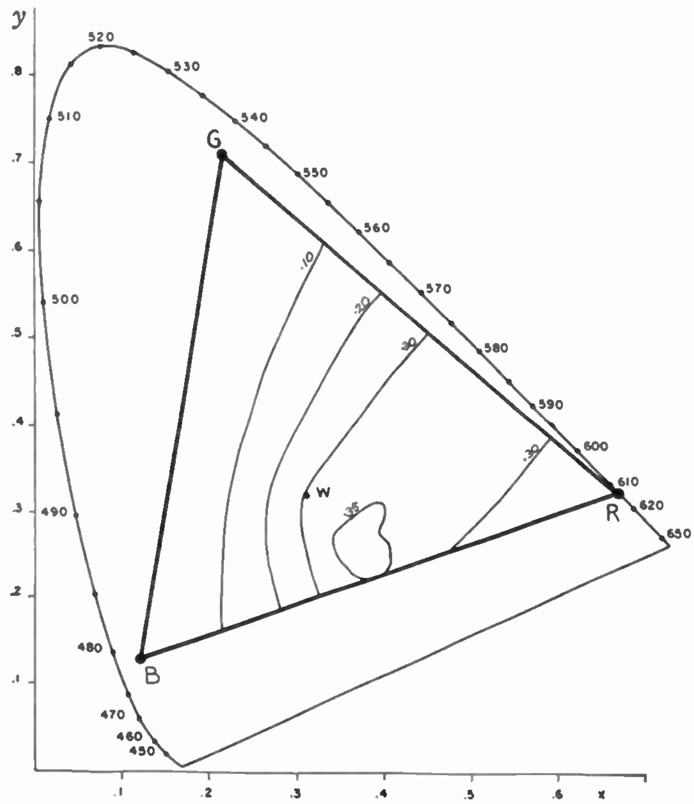

Fig. 22—Maximum luminosity demand contours of red primary—primaries *A*.

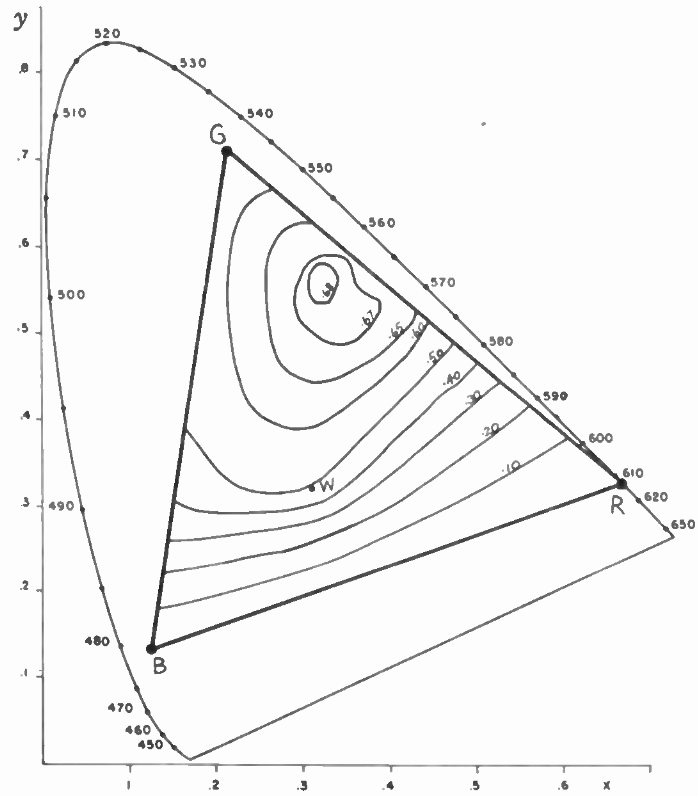

Fig. 23—Maximum luminosity demand contours of green primary—p-imaries *A*.

Examining the demand contours discloses some interesting facts. For example, with primaries *C*, the red, green, and blue demands when reproducing white are 0.23, 0.67, and 0.052, respectively. But the demands for these primaries can rise as high as 0.3, 0.72, and 0.06, so that the maximum luminosity demand of a primary does not occur at white. We can draw up a table illustrating this (Table I).

TABLE I

Table of Luminosity Demand

Primary		Demand at White	Maximum Demand	Ratio Max. demand / White demand
Primary *C*	Red	0.23	0.3	1.30
	Green	0.67	0.72	1.07
	Blue	0.052	0.06	1.15
Primary *A*	Red	0.3	0.35	1.17
	Green	0.48	0.68	1.41
	Blue	0.2	0.20	1.00

The above table enables one to calculate the maximum amount of signal that may be applied to each color channel at white reproduction, if distortion at other colors is to be avoided.

V. Conclusion

While the problems to which this method has been applied are in the field of color reproduction, it is believed that there are many other problems in which the method will be found useful. A unique feature is its ability to provide either a powerful means of theoretical analysis coupled with the clearness of perception characteristic of geometric analysis, or a convenient graphical tool for obtaining numerical results with rapidity. As such, it is believed to represent a new instrument for the use of colorists in all fields.

APPENDIX

Note on possible values of all anharmonic ratios of four points taken in various orders.

Let $(ABCD)=K$.
It is required to find all the possible values that the ratio of these four points can assume as the order is changed.

(1)
$$(ABCD) = \frac{AC}{BC}:\frac{AD}{BD} = K$$
$$(ABDC) = \frac{AD}{BD}:\frac{AC}{BC} = \frac{1}{K}$$
$$(BACD) = \frac{BC}{AC}:\frac{BD}{AD} = \frac{1}{K}.$$

Therefore, interchanging the first and second or third and fourth elements changes the value from K to $1/K$.

(2)
$$(ACBD) = \frac{AB}{CB}:\frac{AD}{CD}$$
$$= -\frac{AB}{BC}:\frac{AD}{BD-BC}$$
$$= -\frac{AC-BC}{BC}\cdot\frac{BD-BC}{AD}$$
$$= -\left(\frac{AC}{BC}-1\right)\left(\frac{BD}{AD}-\frac{BC}{AD}\right)$$
$$= \left(1-\frac{AC}{BC}\right)\left(\frac{BD}{AD}-\frac{BC}{AD}\right)$$
$$= \frac{BD-BC}{AD} - K + \frac{AC}{BC}\frac{BC}{AD}$$
$$= \frac{CD}{AD}+\frac{AC}{AD} - K$$
$$= 1-K.$$

Similarly,
$$(DBCA) = 1-K.$$

Thus interchanging the second and third or fiest and fourth elements changes the value of the ratio from K to $1-K$.

(3)
$$(CBAD) = 1-(CABD) \text{ from (2)}$$
$$= 1-\frac{1}{ACBD} \text{ from (1)}$$
$$= 1-\frac{1}{1=(ABCD)} \text{ from (2)}$$
$$= 1-\frac{1}{1-K}$$
$$= \frac{K}{K-1}.$$

Similarly
$$ADCB = \frac{K}{K-1}.$$

Thus, interchanging the first and third or second and fourth elements changes the value from K to $K/(K-1)$. Thus we see that

$$(ABCD) = K = (BADC)$$
$$(ABDC) = \frac{1}{K} = (BACD)$$
$$(ACBD) = (1-K) = (CADB)$$
$$(CBAD) = \frac{K}{(K-1)} = (BCDA).$$

Following is a tabulation of the six possible values that the anharmonic ratio can assume, and the corresponding element orders:

TABLE II

K	$\frac{1}{K}$	$1-K$	$\frac{1}{1-K}$	$\frac{K}{K-1}$	$\frac{K-1}{K}$
ABCD BADC CDAB DCBA	ABDC BACD CDBA DCAB	ACBD BDAC CADB DBCA	ACDB BDCA CABD DBAC	ADCB BCDA CBAD DABC	ADBC BCAD CBDA DACB

One interesting result is apparent from Table II; namely, that $(ABCD)=(DCBA)$. Therefore, if an anharmonic pencil is drawn on transparent material, it can be used either side up without affecting its value. Thus, a pencil having a variable third ray can also serve as one with a variable second ray, and one with a variable fourth ray will also serve as a pencil with a variable first ray. Thus the solution of all types of color-mixture problems can be obtained with just two graduated anharmonic pencils.

An Approach to the Approximate Solution of the Ionosphere Absorption Problem*

JAMES E. HACKE, JR.†

Summary—A series of parabolic approximations has been obtained for portions of the Chapman distribution and its product with the collisional frequency. By their use, an improved approximate solution has been found for the "true" and the group height of reflection, and for the absorption in the region, under conditions of (1) vertical incidence, (2) wave frequency greater than the maximum collision frequency and less than the critical frequency for the region, and (3) with the earth's magnetic field neglected.

These improved analytic approximations are compared with the usual parabolic approximation and with numerical approximations obtained by other workers.

Introduction

THE CHAPMAN DISTRIBUTION,[1] derived from theoretical considerations with certain simplifying assumptions, has been accepted as representing actual conditions at least in the E and the F_1 layers of the ionosphere. Solution of the problems of group delay and of absorption of a wave reflected in such a region requires, however, integration of functions of this distribution with finite limits; these integrals have not yet been analytically evaluated.

Two approaches to the solution of these problems have been attempted in the past. One is to use a parabolic approximation to the Chapman distribution. This method has the advantage of simplicity, but leads to results that are very approximate, especially for the E layer and for low ratios of frequency to critical frequency. The other approach is that of numerical integration; the results are as accurate as one cares to make them, but may be extended to oblique incidence only with great difficulty.

This paper extends the parabolic approximation by fitting an additional parabola to the lower edge of the Chapman distribution, and by fitting a parabola to the distribution of the product of ion density and collisional frequency. It is possible in this way to obtain analytic expressions for the group delay, and for the absorption of a wave reflected from the ionosphere, which give values much closer than the single-parabola approximation to those obtained by numerical integration.

Throughout this paper, the following limiting assumptions are made: (1) the wave is incident normally on the layer; (2) the wave frequency is less than the critical frequency of the layer, and greater than the maximum collisional frequency in the region of appreciable absorption and refraction; and (3) the effects of the earth's magnetic field are ignored.

* Decimal classification: R113.22. Original manuscript received by the Institute, October 20, 1947. Presented, joint meeting U.R.S.I., American Section, and I.R.E., Washington Section, Washington, D. C., October 22, 1947.

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[1] S. Chapman, "The absorption and dissociative or ionizing effect monochromatic radiation in an atmosphere on a rotating earth," Part I, *Proc. Phys. Soc.*, vol. 43, pp. 26–45; January, 1931.

Normalization of the Chapman Distribution

Chapman[1] derived the following expression for rate of ion production I versus height h above a rotating earth, due to monochromatic ionizing radiation, as a function of the sun's zenith angle χ:

$$I = I_0 \exp(1 - z - \epsilon^{-z} \sec\chi) \quad (1)$$

where

$I_0 = \beta S_\infty / H\epsilon$

$z = (h - h_0)/H$

ϵ = the base of Naperian logarithms

β = the ionization produced by unit quantity of incident radiation

S_∞ = the surface density of radiation energy incident on the atmosphere

H = the "scale height" of the atmosphere in the region where the ionization is produced

h_0 = the height at which $I = I_0$.

Now the equation of mass action in the ionosphere may be written:

$$dN/dt = I - \alpha N^2$$

where

N = the ion density in the ionosphere

α = the recombination coefficient, assumed independent of I and N.

If the ionosphere is in approximate equilibrium, $dN/dt \doteq 0$, and

$$N \doteq \sqrt{(I/\alpha)}.$$

From (1),

$$N = N_0 \exp \tfrac{1}{2}(1 - z - \epsilon^{-z} \sec\chi) \quad (2)$$

where $N_0 = \sqrt{(I_0/\alpha)}$.

In (2), substitute

$$x = z - \ln \sec\chi; \quad (3)$$

then,

$$N = N_0\sqrt{(\sec\chi)} \exp \tfrac{1}{2}(1 - x - \epsilon^{-x}),$$
$$\equiv N_m Ch(x), \quad (4)$$

where

$$N_m \equiv N_0\sqrt{(\sec\chi)}, \quad (5)$$

$$Ch(x) \equiv \exp \tfrac{1}{2}(1 - x - \epsilon^{-x}). \quad (6)$$

Thus (3) and (5) suffice to describe the variation of ionosphere characteristics with the sun's zenith angle; this variation is separated from that of ion density with height at any given instant. This latter variation is given, relative to conditions at the maximum for the instant, by (6).

Approximations to the Chapman Distribution

Variation of $Ch(x)$ with x is plotted in Fig. 1. Also plotted is the usual parabolic approximation, denoted

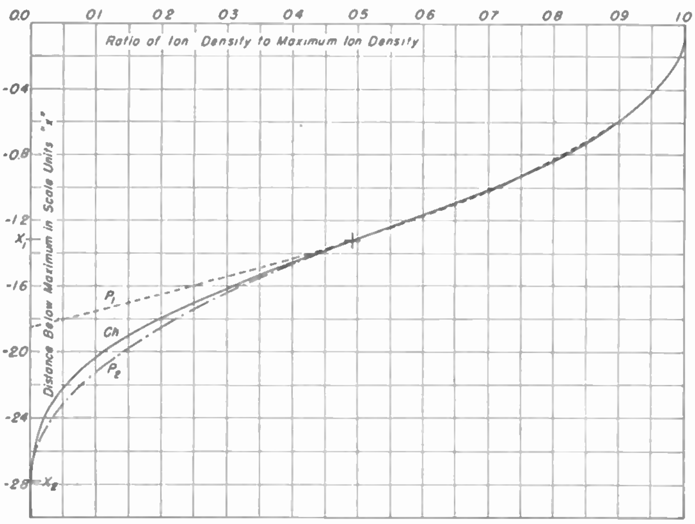

Fig. 1—Parabolic approximations to the Chapman distribution.

by $P_1(x)$. This approximation is given by an equation of the form

$$P_1(x) = 1 - (x/T)^2; \tag{7}$$

here the value of the "half-thickness" T has been chosen to make the parabola coincident with the Chapman distribution at the lower point x_1 of inflection of the Chapman distribution. This yields $x_1 \equiv -\ln u_1 = -\ln(2+\sqrt{3}) = -1.317$; $Ch(x_1) = \exp\ \frac{1}{2}(1 - x_1 - u_1) = 0.4921$; $T = -x_1/\sqrt{1 - Ch(x_1)} = 1.848$. This value of T is very close to the pragmatic choice of Pierce.[2,3]

As will be seen from Fig. 1, this approximation is very close near the maximum of the Chapman distribution, but fails near the lower limits. A second parabola has been fitted in this region, with the conditions that it have the same value and slope at x_1, as does the Chapman distribution. This parabola is of the form

$$P_2(x) = A(x - x_2)^2; \tag{8}$$

the parameters are given by $Ch(x_1)$; $Ch'(x_1) = \frac{1}{2}(u_1 - 1)Ch(x_1)$; $A = (1/16)(u_1 - 1)^2 Ch(x_1) = 0.2296$; $x_2 = x_1 - 4/(u_1 - 1) = -2.781$. This parabola is used as an approximation in the region between x_2 and x_1.

[2] J. A. Pierce, "True height of an ionospheric layer," ONR Contract N5-ORI-76, Task Order 1, November 15, 1946.
[3] J. A. Pierce, "True height of an ionospheric layer," *Phys. Rev.*, vol. 71, pp. 698–706; May 15, 1947.

The combination of P_2 in the region $x_2 < x < x_1$, and P_1 in the region $x_1 < x < 0$, yields values which nowhere in these regions are in error by more than 4 per cent of the maximum; throughout most of the regions, the approximation is much closer.

If one assumes, as did Chapman, that the atmosphere is chemically homogeneous and isothermal, then the collisional frequency ν of the molecules should obey the law

$$\nu = \nu_0 \epsilon^{-h/H}$$

where ν_0 is the collisional frequency at the surface of the earth in radians per second. A suitable transformation of co-ordinates yields

$$\nu = \nu_m \epsilon^{-z} \tag{9}$$

where

$$\nu_m = (\nu_0 \epsilon^{-h_0/H})/(\sec \chi).$$

The product $N\nu$ can therefore be written

$$N\nu = N_m \nu_m Ch(x) \epsilon^{-x}; \tag{10}$$

this product enters in the expression for the absorption coefficient. Fig. 2 shows the variation of this product

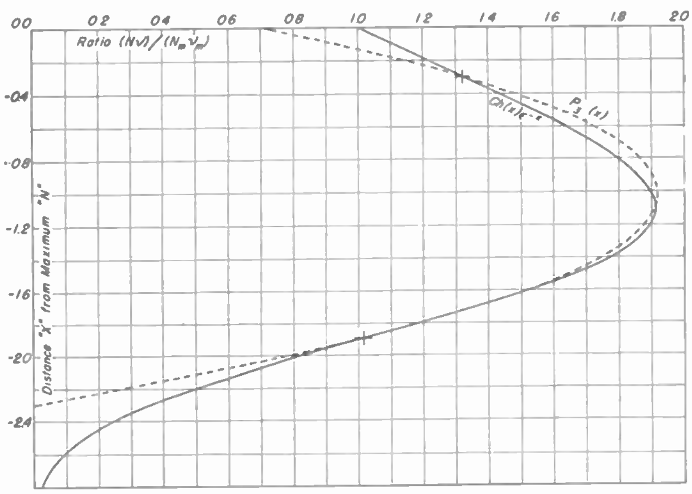

Fig. 2—Product of ionization and collision frequency.

with x; it also shows a parabolic approximation which has been adopted for the product $Ch(x)\epsilon^{-x}$. This approximation is of the form

$$P_3(x) = a_0 + a_1 x + a_2 x^2 \tag{11}$$

where the a_i's are chosen to make the parabola pass through the two points of inflection and the maximum of the distribution. Thus, $a_0 = 0.7055$; $a_1 = -2.382$; $a_2 = -1.1696$.

The "True" and the Apparent Height of Reflection

If the change per wavelength of the index of refraction of the ionosphere be small, then the height at which the velocity of a vertically incident wave becomes zero is approximately the point at which the index of refraction becomes zero. If the wave frequency is much greater than the maximum collisional frequency in the region of appreciable refraction, then the index of refraction μ is given by

$$\mu^2 = 1 - 4\pi Ne^2/(m\omega^2) \tag{12}$$

where e and m are, respectively, the electron charge and mass, and ω is the angular frequency of the wave. At the critical frequency ω_m of the layer, reflection takes place at $x=0$, where $N=N_m$:

$$0 = 1 - 4\pi N_m e^2/(m\omega_m^2);$$

$$\omega_m^2 = 4\pi N_m e^2/m. \tag{13}$$

If we set $R=\omega/\omega_m$ and substitute (13) and (12), we obtain

$$\mu = \sqrt{1 - Ch(x)/R^2}; \tag{14}$$

the approximations to μ given by $P_1(x)$ and $P_2(x)$ are

$$\left.\begin{aligned} \mu &\doteq \sqrt{1 - P_2(x)/R^2}, \quad x_2 < x < x_1; \\ &\doteq \sqrt{1 - P_1(x)/R^2}, \quad x_1 < x < 0. \end{aligned}\right\} \tag{15}$$

The condition $\mu=0$ for reflection yields the solid curve for reflection height x_0 versus frequency, in Fig. 3, when (14) is used, and the dotted curve when (15) are used.

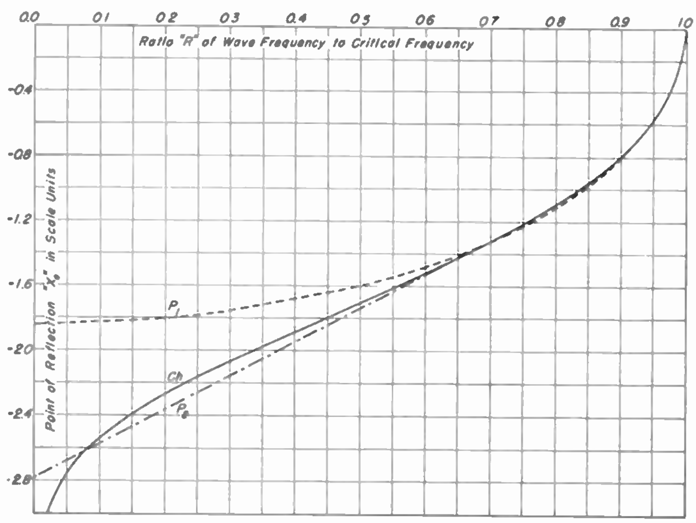

Fig. 3—Point of wave reflections.

These curves show again that the approximations (15) are much closer than the single-parabola approximation.

The apparent height of reflection h' is obtained by multiplying half the elapsed time, between sending and receiving the wave at the earth, by the velocity of light. It can be obtained by integrating, over the upward path, the group velocity of the wave divided by the velocity of light. In the x co-ordinates used here, since the group velocity is the velocity of light divided by the index of refraction,

$$x' = x_L + \int_{x_L}^{x_0} dx/\mu \tag{16}$$

where x_L is an arbitrarily chosen lower limit where $\mu \doteq 1$. Quadrature of the integral in (16) in the exact form has not yet been achieved when x_0 is in the layer; use of the approximations (15) yield tractable integrals, however, and the results are

$$\left.\begin{aligned} x' &\doteq x_2 + (\pi/2)(R/\sqrt{A}), \quad x_2 < x_0 < x_1; \\ &\doteq x_2 + R\theta_1/\sqrt{A} + .TR \ln x_0/(x_1 + \sqrt{x_1^2 - x_0^2}), \\ &\quad x_1 < x_0 < 0 \end{aligned}\right\} \tag{17}$$

where

$$\theta_1 = \cos^{-1} \mu(x_1).$$

If the single parabola P_1 be used as an approximation to the Chapman distribution, one obtains

$$x' \doteq -T + (TR/2) \ln (1+R)/(1-R), \quad -T < x_0 < 0, \tag{18}$$

as has been reported by Appleton and Beynon.[4] The approximations (17) and (18) are plotted in Fig. 4, with

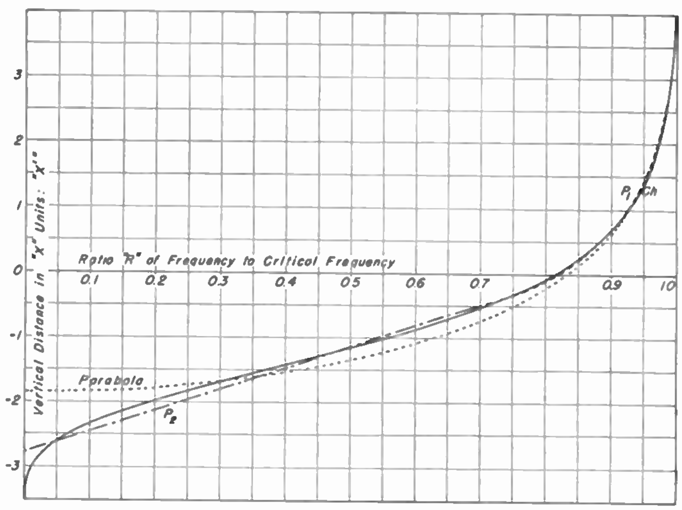

Fig. 4—Apparent height of reflections.

numerical integrations of (16) given by Pierce[2,3] and Jaeger.[5] The results given by (17) agree much more closely with the results of the numerical integrations than do those given by (18). The two numerical integrations, obtained independently, check within 0.01 "x" units over most of the range.

Absorption and the Reflection Coefficient

Under the conditions outlined above, the absorption coefficient K is given by

[4] E. V. Appleton and W. J. G. Beynon, "The application of ionospheric data to radio-communication problems," Part I, *Proc. Phys. Soc.*, vol. 52, pp. 518–533; July, 1940.

[5] J. C. Jaeger, "Equivalent path and absorption in an ionospheric region," *Proc. Phys. Soc.*, vol. 59, pp. 87–96; February, 1947.

$$K = 2\pi e^2 N\nu/(mc\mu\omega^2),$$
$$= K_m Ch(x)\epsilon^{-x}/(\mu R^2) \qquad (19)$$

where, by use of (10) and (13),

$$K_m = \nu_m/2c.$$

The reflection coefficient ρ, which, when divided by twice the "true" height of reflection, gives the ratio of received to transmitted wave amplitude, is given by

$$\rho = \exp -2\int_{xL}^{x_0} K ds \qquad (20)$$

where $ds = Hdx$ is an element of the path.

With the aid of (19), the integral on the right of (20) takes the form

$$\int_{xL}^{x_0} K ds = K_m H \int_{xL}^{x_0} Ch(x)\epsilon^{-x} dx/(\mu R^2). \qquad (21)$$

This integration cannot be performed exactly; but when the approximation (11) is substituted for $Ch(x)\epsilon^{-x}$, and the approximations (15) for μ, the integration can be performed:

$$\rho \doteq \exp -(\nu_m H/c)\{[(\pi/2 - \theta_3)/\sqrt{A}][P_3(x_2)/R + a_2R/(2A)] + [\mu_3/(2A)][2a_1 + a_2(x_3 + 3x_2)]\}, \quad x_3 < x_0 < x_1 \qquad (22)$$

$$\doteq \exp -(\nu_m H/c)\left\{\frac{(\theta_1 - \theta_3)}{\sqrt{A}}\left[\frac{P_3(x_2)}{R} + \frac{a_2R}{2A}\right] - \frac{(\mu_1 - \mu_3)}{2A}[2a_1 + 3a_2x_2] - \frac{a_2}{2A}(\mu_1x_1 - \mu_3x_3) + \frac{T}{R}\left[a_0 + \frac{a_2x_0^2}{2}\right]\ln\frac{x_0}{x_1 + TR\mu_1} - T^2\mu_1\left(a_1 + \frac{a_2x_1}{2}\right)\right\}, \quad x_1 < x_0 < 0. \qquad (23)$$

Using the single-parabola approximation, one obtains:

$$\rho \doteq \exp -(\nu_m H/c)\left\{\frac{1}{R^2}\left[-a_0(T + x_3) + \frac{a_1}{2}(T^2 - x_3)^2 - \frac{a_2}{3}(T^3 + x_3^3)\right] + \frac{T}{4R}(2a_0 + a_2x_0^2)\ln\left[\frac{1+R}{1-R}\right] - T^2[a_1 - a_2T/2]\right\}, \qquad (24)$$

where

$x_3 = -2.299$ is the negative root of $P_3(x) = 0$

$\mu_1 = \mu(x_1)$

$\mu_3 = \mu(x_3) \doteq \sqrt{1 - P_2(x_3)/R^2}$

$\theta_3 = \cos^{-1}\mu_3$.

The quantity $-c(ln\rho)/(\nu_m H)$ is plotted in Fig. 5 as given by the approximations (22), (23), and (24), and as Jaeger obtained by numerical integration.

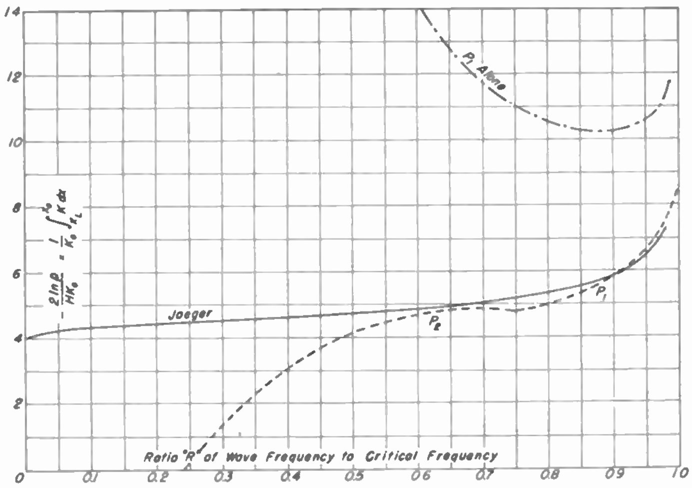

Fig. 5—Integral of absorption coefficient

Conclusions

Algebraic approximations to the Chapman distribution, and to its product with collisional frequency, yield integrable expressions for apparent height of reflection and for reflection coefficient at vertical incidence, under the assumptions outlined. The results agree well with those obtained by numerical methods. It is believed possible to remove some or all of the restrictions assumed in this paper, and thus to obtain approximate analytical solutions to the general problem of group delay and absorption.

The approximations given are by no means the closest that can be obtained. Perhaps the principal value of the present treatment is in its pointing out that approximations of very fair precision can be made to these distributions.

Acknowledgment

The described method of treatment was developed as a part of research work being carried out by The Pennsylvania State College for Watson Laboratories, Air Matériel Command, Red Bank, N. J., under Contract No. W28-099-ac-143. Direction of this research is by A. H. Waynick of The Pennsylvania State College; his suggestions and criticisms were of material help in obtaining the results given here.

On the Representation and Measurement of Waveguide Discontinuities*

NATHAN MARCUVITZ†, ASSOCIATE, I.R.E.

Summary.—**The principal aims of this paper are twofold: (1) to discuss and interrelate the various equivalent circuit representations of a general 2*N*-terminal waveguide structure that are obtained on different choices of terminal planes; and (2) to describe a precision method for measuring the circuit parameters of such structures. Basic to both of these considerations is a tangent relation introduced by Weissfloch to describe and measure the input-output behavior of a four-terminal waveguide structure.**

Introduction

In recent years, the treatment of high-frequency electromagnetic boundary-value problems, involving waveguide discontinuities, has been systematized into a form of waveguide network analysis that forms a natural extension of the familiar lumped-circuit network analysis. The concept of wave impedance introduced by Schelkunoff is basic to this high-frequency network analysis. Suitably defined, the impedance point of view permits the reformulation of waveguide field problems as network problems whose basic elements are lumped-constant circuits and distributed-constant transmission lines. The theoretical determination of the network parameters that characterize a wide variety of waveguide structures has been accomplished by an integral equation method of analysis introduced and systematically employed by Schwinger, et al.[1] A corresponding experimental determination of network parameters is possible and has been employed by a number of workers. Waveguide network measurements can be performed in a variety of ways. One method is based on the well-known open- and short-circuit, etc., technique employed at low frequencies. An alternative method first introduced by Weissfloch[2] is based on the expression of the input-output impedance relation of a four-terminal network in the form of a tangent or transformer relation. The latter method appears more desirable in precision waveguide measurements, and is employed in this paper. The tangent relation will also be employed to obtain various equivalent-circuit representations for waveguide discontinuities by reference-plane transformations.

I. Waveguide Network Analysis

As a preliminary to the discussion of waveguide network analysis, it is desirable to recall the well-known analysis of low-frequency networks based on Kirchhoff's laws. These laws interrelate the voltages and currents at the terminals of a lumped-constant network in terms of the impedances (or admittances) of the circuit elements that compose the network. For waveguide networks, there exist voltage-current relations of the same general form as the Kirchhoff relations. This, of course, is to be expected, since such relations are a consequence of the linear and reciprocal nature of the electromagnetic field equations and apply equally well to high-frequency waveguide networks and to low-frequency lumped-constant networks.

To employ a waveguide circuit analysis analogous to the use of Kirchhoff's laws for lumped-constant networks, it is necessary to define explicitly the meaning of voltage and current. To do so, we shall first consider how certain electromagnetic boundary-value problems can be reformulated as microwave network problems. An electromagnetic boundary-value problem involves the determination of the electric field $\boldsymbol{E}$ and magnetic field $\boldsymbol{H}$ at every point within a closed region of space. These fields are required to satisfy the Maxwell field equations and to assume prescribed values on the surface enclosing the given region. According to a fundamental theorem,[3] a unique solution to this problem exists provided the tangential component of either the electric field *or* the magnetic field is specified at the boundary surface. In waveguide problems, one is generally interested in the solutions for the fields not everywhere within the given region but rather only in certain "far" regions wherein the fields are of simple form and easily accessible to measurement.

To take a specific problem, consider the boundary-value problem associated with the general waveguide structure represented in Fig. 1, wherein the numbers (1) to (N) represent waveguides of arbitrary

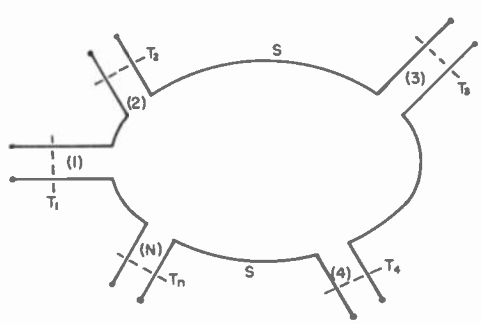

Fig. 1—2N-terminal waveguide structure.

* Decimal classification: R118. Original manuscript received by the Institute, July 21, 1947; revised manuscript received, October 30, 1947.

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[1] J. Schwinger, "Theory of Guided Waves," to be published.

[2] A. Weissfloch, "Ein transformation über verlustose vierpole und seine anwendung," *Hochfrequenz und Elektroakustik*, vol. 60, pp. 67–73; 1942.

[3] J. A. Stratton, "Electromagnetic Theory," McGraw-Hill Book Co., New York, N. Y., 1941; sec. 9.2.

cross section bounded by metallic conductors. The boundary conditions appropriate to this problem are that the electric field components tangential to the metallic boundary surface S, indicated by the solid lines, vanish, and the magnetic field components tangential to the "terminal" boundary surfaces $T_1, \cdots T_n$, indicated by dashed lines, assume prescribed but arbitrary values. By the uniqueness theorem quoted above, the electric field, for example, can be found at every point within the given region. In particular, the tangential electric field can be ascertained at any terminal surface T_i located relatively "far" from the junction region. Because of the linear nature of the electromagnetic field, it is possible to deduce immediately, without solving any field equations, that the transverse electric field at any terminal surface T_i must be linearly related to the transverse components of the exciting magnetic fields at any or all the terminal surfaces $T_1 \cdots T_n$.

Because of the simplicity of the waveguide fields in the "far" regions, it is possible to introduce, as measures of the amplitudes of the transverse electric field $\boldsymbol{E}_t$ and the transverse magnetic field $\boldsymbol{H}_t$ at the terminal surface T_i, the quantities I_i and V_i defined by the relations:

$$\begin{aligned} \boldsymbol{H}_t(x_i, y_i) &= I_i \boldsymbol{h}(x_i, y_i) \\ \boldsymbol{E}_t(x_i, y_i) &= V_i \boldsymbol{e}(x_i, y_i) \end{aligned} \tag{1}$$

where $\boldsymbol{e}(x_i, y_i)$ and $\boldsymbol{h}(x_i, y_i)$ are known vector functions indicative of the transverse form of the electric and magnetic fields (of the one propagating mode) at the ith terminal surface. The voltage V_i and current I_i, hereby defined, completely characterize the fields at the ith terminal surface. There is a certain arbitrariness in these definitions dependent on the normalization of $\boldsymbol{e}$ and $\boldsymbol{h}$. Once the normalization is fixed, voltage and currents have a unique significance in terms of the fields just as in ordinary circuit theory. In fact, in cases that permit comparison, it is possible to choose the normalization such that the resulting definitions of V_i and I_i agree with the customary low-frequency definitions. However, this point is not to be stressed, since most waveguide properties depend on relative impedances and these are independent of the particular normalization employed. There is one restriction to the arbitrariness of normalization that is sufficient to insure the validity of the reciprocity relations ($Z_{ij}=Z_{ji}$) employed below[1,4]: the normalization must be such that the total complex power flowing along the waveguide at the ith terminal surface is V_iI_i, where V_i and I_i are r.m.s. quantities.

In view of (1), one may write the linear relations between the electric fields set up at all terminal surfaces and an exciting magnetic field applied *only* at the ith terminal surface as

[4] S. A. Schelkunoff, "Electromagnetic Waves," D. Van Nostrand Co., Inc., New York, N. Y., 1943; sec. 11.10.

$$\left.\begin{aligned} V_1' &= Z_{1i}I_i \\ V_2' &= Z_{2i}I_i \\ &\vdots \\ V_n' &= Z_{ni}I_i \end{aligned}\right\} \tag{2}$$

where the primes denote partial voltages set up by the action of the ith current only. The proportionality factors Z_{ji} are called impedance coefficients and for a nondissipative structure are purely imaginary. The partial voltages set up by excitation with any other current can be likewise represented. The total voltage at any terminal surface due to the simultaneous action of all the currents can then be obtained by superposition.

Rather than illustrate the resulting form of the network equations for this general case, we shall discuss a special case of practical importance wherein geometrical symmetries in the waveguide structure serve to impose relations among the Z_{ij}. In Fig. 2(a) a symmetrical junction of three rectangular guides is illustrated. For comparison, an ordinary lumped-constant six-terminal network possessing the same symmetry is shown in Fig. 2(b). It is assumed that the frequency is such that only the dominant mode can be propagated in each waveguide and, in addition, that the excitation is such that the electric field of the dominant mode is perpendicular to the plane of the figure. This is the case of the so-called magnetic-plane tee. The following analysis applies also to the case where the angle between guides (1) or (2) and guide (3) is other than the right angle indicated in Fig. 2(a).

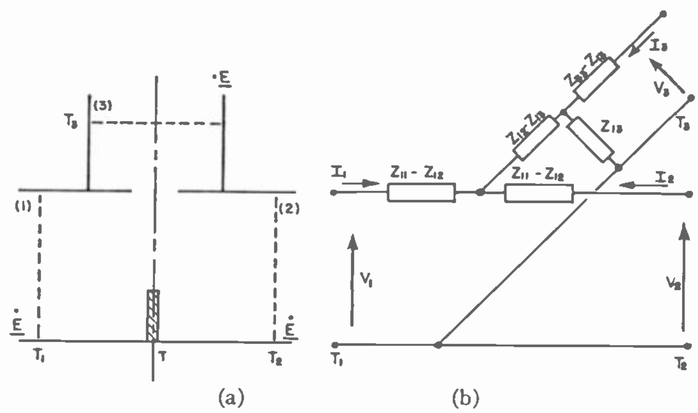


Fig. 2—(a) Top view of *H*-plane tee. (b) Equivalent circuit.

In conformity with the symmetry of the structure, terminal planes T_1, T_2, T_3 are chosen in the symmetrical manner indicated in Fig. 2(a). The voltage and current at each of the three terminal planes are defined as V_1 and I_1, V_2 and $-I_2$, V_3 and $-I_3$. The choice of sign is such that, in each of the guides, the positive direction of power flow is toward the junction. The linear relations (2) describe the partial voltages produced by a current I_1 when all terminals other than T_1 are open-circuited. The corresponding partial voltages produced by I_2 follow from those produced by I_1 because of the symmetry of the structure. For, on a 180° rotation of the structure about the symmetry plane T, it is apparent that the field configuration produced by I_1 becomes identical with that produced by I_2. Hence, the impedance coefficients for the former case apply also to the latter case. The form of the impedance coefficients defining the partial voltages produced by I_3 is obtained either by a symmetry or reciprocity argument. By superposition, the voltages produced by the simultaneous action of the currents I_1, I_2, and I_3 are, therefore,

$$\begin{aligned} V_1 &= Z_{11}I_1 + Z_{12}I_2 + Z_{13}I_3 \\ V_2 &= Z_{12}I_1 + Z_{11}I_2 + Z_{13}I_3 \\ V_3 &= Z_{13}I_1 + Z_{13}I_2 + Z_{33}I_3. \end{aligned} \tag{3}$$

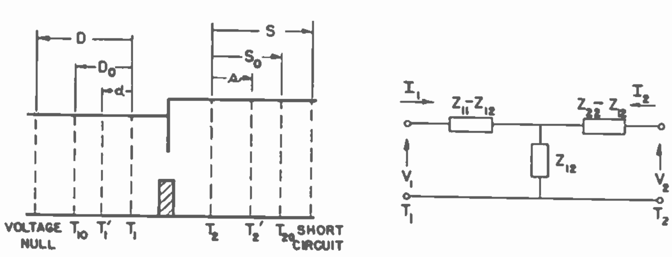
These are the network equations descriptive of the given symmetrical waveguide structure. It is evident that the application of the usual Kirchhoff mesh analysis to the circuit in Fig. 2(b) yields exactly the same network equations, thus indicating that this network is the equivalent circuit representation of the waveguide structure under consideration.

Although the above analyses have been carried through on an impedance basis, corresponding analyses are possible on an admittance basis. Whatever the type of analysis, it is to be emphasized that the linear and reciprocal nature of the field equations permit one to write down the network equations for the waveguide structure by an analysis of the Kirchhoff type. The explicit determination of the impedance (or admittance) parameters that characterize the structure may then be determined either theoretically or experimentally.

II. Measurement of Circuit Parameters

(a) *Four-Terminal Structures*

The measurement of the impedance parameters of a general nondissipative four-terminal structure will be considered first, as it is basic to the measurement of $2N$-terminal structures. Such a structure, together with its network representation at terminals T_1 and T_2, is illustrated in Figs. 3(a) and (b). In terms of the impedance



(a) (b)

Fig. 3—(a) Four-terminal waveguide structure. (b) Equivalent circuit.

parameters Z_{11}, Z_{12}, and Z_{22}, the relation between the input impedance Z_{in} at T_1 and the output impedance Z_{out} at T_2 may be expressed as

$$Z_{in} = Z_{11} - \frac{Z_{12}^2}{Z_{22} + Z_{out}}. \tag{4}$$

This impedance relation can, in turn, be rewritten in terms of three new parameters, D_0, S_0, and γ, as the tangent relation[2]

$$\tan 2\pi(D - D_0) = \gamma \tan 2\pi(S - S_0) \tag{5}$$

where the new input-output variables D and S are defined by

$$\begin{aligned} Z_{in} &= \frac{V_1}{I_1} = -jZ_1 \tan 2\pi D \\ Z_{out} &= -\frac{V_2}{I_2} = +jZ_2 \tan 2\pi S \end{aligned} \tag{6}$$

Z_1 and Z_2 being the characteristic impedance of the input and output guides, respectively. The relation between the parameters Z_{11}, Z_{12}, and Z_{22} and the parameters γ, D_0, and S_0 may be obtained on rewriting (4) as

$$Z_{in}Z_{out} + Z_{22}Z_{in} - Z_{11}Z_{out} - (Z_{11}Z_{22} - Z_{12}^2) = 0 \tag{7}$$

and on rewriting (5) as

$$\begin{aligned} (\beta - \alpha\gamma) \tan 2\pi D \tan 2\pi S + (1 + \alpha\beta\gamma) \tan 2\pi D \\ - (\alpha\beta + \gamma) \tan 2\pi S - (\alpha - \beta\gamma) = 0 \end{aligned} \tag{8}$$

where

$$\alpha = \tan 2\pi D_0, \qquad \beta = \tan 2\pi S_0. \tag{9}$$

Employing (6) to identify corresponding terms in (7) and (8), one then finds that the desired relations are

$$\begin{aligned} -j\frac{Z_{11}}{Z_1} &= -\frac{\alpha\beta + \gamma}{\beta - \alpha\gamma} = a \\ -j\frac{Z_{22}}{Z_2} &= \frac{1 + \alpha\beta\gamma}{\beta - \alpha\gamma} = c \\ \frac{Z_{11}}{Z_1}\frac{Z_{22}}{Z_2} - \frac{Z_{12}^2}{Z_1Z_2} &= \frac{\alpha - \beta\gamma}{\beta - \alpha\gamma} = b. \end{aligned} \tag{10}$$

Equations (10) are not valid for the degenerate case $\alpha = \beta = 0$ as is to be expected from the corresponding degeneracy in the impedance representation of an ideal transformer. From (10) it also follows that

$$\frac{Z_{12}^2}{Z_1Z_2} = \frac{\gamma(1 + \alpha^2)(1 + \beta^2)}{(\beta - \alpha\gamma)^2}. \tag{11}$$

The indeterminacy in the sign of Z_{12} is characteristic of input-output impedance relations, and implies that equivalent circuits differing only in the sign of Z_{12} yield the same input-output relation. The ambiguity can be resolved on determination of either the relative phase or the transfer impedance between input and output terminals.

Explicit expressions for α, β, and γ are found, on inversion of (12), to be

$$\begin{aligned} \alpha &= \left[\frac{1 - a^2 + c^2 - b^2}{2(a - bc)}\right] \pm \sqrt{[\quad]^2 + 1} \\ \beta &= \left[\frac{1 + a^2 - c^2 - b^2}{2(c - ab)}\right] \mp \sqrt{[\quad]^2 + 1} \end{aligned} \tag{12}$$

$$-\gamma = \left[\frac{1 + a^2 + c^2 - b^2}{2(b + ac)}\right] \pm \sqrt{[\quad]^2 - 1}.$$

In each equation, the bracketed expressions within and outside the square root are identical. The $\pm$ indicates that either the upper or the lower signs in the expressions for α, β, and γ yield a tangent relation (5) equivalent to the impedance relation (4). From the form of (12), it is evident that the two sets are positive or negative reciprocals of one another. In the following, the upper set of signs for which $-\gamma > 1$ will always be employed.

Equations (4) to (12), excluding (6), are expressed in terms of impedances but apply equally well to a representation in terms of admittances if Z is everywhere replaced by Y, and if

$$\alpha = -\cot 2\pi D, \qquad \beta = -\cot 2\pi S. \qquad (13)$$

The definitions of D and S, given in (6), still apply to this case.

As noted by Weissfloch,[2] the equivalence between (4) and (5) can be clearly interpreted physically. In the first place, it is apparent from (6) that, if the output impedance Z_{out} is produced by a short circuit, a distance S away from the terminal plane T_2, then D is the distance from the terminal plane T to the voltage minimum; i.e., zero, in the input line (Fig. 3(a)). The distances D and S (as likewise the distances D_0 and S_0, to be interpreted below) are all measured ***in guide wavelengths***; i.e., D is the geometrical distance divided by the guide wavelength in the ***input*** line, and S is the geometrical distance divided by the guide wavelength in the output line. All distances are counted positive in the direction away from the junction. As a consequence, (5) states that, at terminal planes T_{10} and T_{20}, located a distance D_0 and S_0 away from T_1 and T_2, the relative input impedance, $\tan 2\pi(D-D_0)$, is a constant, $n^2 = -\gamma$, times the relative output impedance $+j \tan 2\pi(S-S_0)$. Therefore, if the terminal planes T_{10} and T_{20} are chosen as the input and output terminals, respectively, the equivalent circuit representation of the structure in Fig. 3(a) is an ideal transformer of transformation ratio n^2.

Although the change in variable in the transition from (4) to (5) is valid for both dissipative and nondissipative networks, the simple transformer interpretation in which D and S appear as real geometrical distances is valid only in the lossless case. In the dissipative case, the variable D as well as the parameters D_0, S_0, and γ are complex quantities.

For nondissipative waveguide discontinuities of the four-terminal type, the simple interpretation of D and S as geometrical distances provides the basis for a simple method of measurement of the unknown parameters D_0, S_0, γ in (5), and hence of the equivalent circuit parameters Z_{11}, Z_{12}, Z_{22} of (4). The former parameters may be measured,[2] for example, by placement of matched terminations on one side of the discontinuity and measurement of the standing-wave ratio and minimum position on the other side by means of a standing-wave detector, and conversely. The accuracy of such measurements is subject to the usual criticism associated with isolated point measurements. When a more precise method of measurement is desired, it is necessary to automatically utilize a whole series of point measurements. A calibrated shorting plunger is placed at a distance S away from an arbitrarily chosen output reference plane of the discontinuity and the distance D between the minimum of the standing-wave pattern (of infinite standing-wave ratio), and an arbitrarily chosen input reference plane is measured by some detecting means.[5]

The resulting variation of D versus S may have either of the forms shown in Fig. 4, depending on the magnitude of γ. The curves are repetitive in D and S with

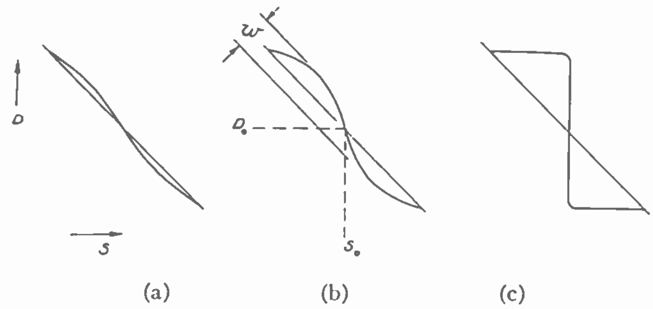


Fig. 4—Tangent relation for various values of $-\gamma$; (a) $-\gamma \simeq 1$, (b) $-\gamma > 1$, (c) $-\gamma >> 1$.

a period of a half wavelength. The dependence of the shape of the above curves on the parameters D_0, S_0, γ can be readily ascertained by taking the derivative of (5) to find the slope

$$\frac{dD}{dS} = \gamma \frac{1 + \tan^2 2\pi(S - S_0)}{1 + \gamma^2 \tan^2 2\pi(S - S_0)}. \qquad (14)$$

The quantity γ (of absolute magnitude greater than one) is seen to be the maximum slope and occurs at the point $S = S_0$ and $D = D_0$. The minimum slope is $1/\gamma$ and occurs at a point a quarter wavelength away from D_0, S_0. As a result of these or other identifications, approximate values of D_0, S_0, γ are immediately ascertained.

The precision analysis of the experimental data requires the determination of a set of values γ, D_0, S_0 which, on insertion into (5), furnishes a tangent curve identical to the experimental curve within the accuracy of the experiment. The required parameters are evaluated by a successive approximation analysis which depends on the magnitude of γ. Almost-matched waveguide structures have a $-\gamma$ value of approximately unity and, consequently, give rise to a tangent curve (Fig. 4(a)) from which it is difficult to evaluate and locate the points of maximum or minimum slope. To obtain a first approximation to the values of γ, D_0, S_0, in

[5] If a slotted section detector is employed, it should be calibrated to compensate for the presence of the slot.

such cases, it is convenient, to consider the form (5) assumes for $\gamma=-1-\epsilon$ (ϵ small). Adding $\tan 2\pi(S-S_0)$ and dividing through by $1-\tan 2\pi(D-D_0) \tan 2\pi(S-S_0)$ on both sides of (5), one obtains

$$\tan 2\pi(D+S-D_0-S_0) = -\frac{\epsilon}{2}\frac{\sin 4\pi(S-S_0)}{1+\epsilon\sin^2 2\pi(S-S_0)}, \qquad (15a)$$

or, for small ϵ,

$$D+S \cong D_0+S_0-\frac{\epsilon}{4\pi}\sin 4\pi(S-S_0). \qquad (15b)$$

Thus, if the experimental data is plotted in the form $D+S$ versus S instead of D versus S, the curve shown in Fig. 5 is obtained. The values of D_0+S_0, S_0, $\epsilon/2\pi$ can be easily read from this curve and furnish first approximations to the required parameters γ, D_0, and S_0.

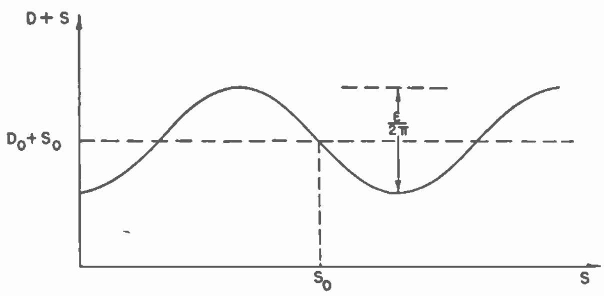


Fig. 5—Plot of data for $-\gamma \cong 1$.

For waveguide discontinuities with $-\gamma$ greater than unity, it is convenient to obtain a first approximation to the parameters γ, D_0, S_0 with the aid of the experimental plot (Figs. 4(b) and (c)) of D versus S. The first approximation to γ may be found by averaging the maximum slopes and reciprocals of the minimum slopes. An additional value for the average may be obtained,[2] using (14) and some trigonometry, as

$$-\gamma = \cot^2 2\pi\left(\frac{1}{8}-\frac{\sqrt{2}}{4}w\right) \qquad (16)$$

where, as shown in Fig. 4(b), w is the width of the tangent curve between the points of slope -1. First approximations to D_0 and S_0 may be obtained from the location of the points of maximum and minimum slope by appropriate averages.

In the above, it has been most convenient to consider curves of relative rather than absolute values of D and S, since this avoids the introduction of cumbersome factors when the input and output guides are different. Practically, however, it is most expeditious to plot the absolute measured values of D and S. The determination of γ, etc., from the latter curve involves the use of suitable factors of $\lambda_{g1}/\lambda_{g2}$, the guide wavelengths, in the input and output guides.

With the knowledge of the first approximations to γ, D_0, S_0, a tangent curve of D versus S can be computed by (5) and compared with the experimental data. A convenient mode of comparison that facilitates the determination of a second approximation, if the first is not sufficiently accurate, is provided by a plot of the difference between the experimental and computed values of D against values of S corresponding to the experimental points. The resulting error curve of $\Delta D = D_{exp}-D_{comp}$ versus S may or may not possess any regularity. If the error curve exhibits no regularity, the accuracy of the data does not warrant further approximations. If regularity is exhibited, the error curve can be further analyzed to obtain corrections $\Delta\gamma$, ΔD_0, ΔS_0 to the first approximation values.

The corrections may be determined by first finding the theoretical curve of ΔD versus S arising from variations $\Delta\gamma$, ΔD_0, ΔS_0 in (5). This curve, as obtained by taking the differential of (5), may be put into the form

$$\Delta D = \Delta D_0 - \frac{\gamma\Delta S_0 - \dfrac{\sin 4\pi(S-S_0)}{4\pi}\Delta\gamma}{\cos^2 2\pi(S-S_0)+\gamma^2\sin^2 2\pi(S-S_0)}. \qquad (17)$$

The desired corrections are given by those values of $\Delta\gamma$, ΔD_0, ΔS_0 which, on substitution into (17), best reproduce the error curve. If values of ΔD obtained from the error curve at $S-S_0=0$, 1/8, 1/4 are designated by Δ_0, $\Delta_{1/8}$, $\Delta_{1/4}$, respectively, then a typical set of values for the corrections are found from (17) to be

$$\begin{aligned}\Delta\gamma &= 2\pi[(1+\gamma^2)\Delta_{1/8}-(\Delta_0+\gamma^2\Delta_{1/4})]\\ \Delta D_0 &= \frac{\Delta_0-\gamma^2\Delta_{1/4}}{1-\gamma^2}\\ \Delta S_0 &= \frac{\gamma}{1-\gamma^2}(\Delta_0-\Delta_{1/4}).\end{aligned} \qquad (18)$$

Alternative ways of determining the corrections from the error curve may be devised, depending on the magnitude of γ. For example, if γ is not too large, it is sometimes convenient to use the fact that $\Delta\gamma$ is the slope of the error curve at $S=S_0$. The addition of the corrections (18) to γ, D_0, S_0 yields the second approximation to these parameters. If necessary, additional corrections may be obtained by repetition of the above outlined process.

In typical measurements at $\lambda=3.2$ centimeters, the procedure described above has yielded values of γ, D_0, S_0 which provide a tangent curve that reproduces the experimental data to within 0.0005 λ_g on the average; that is, the error curve has an average amplitude of 0.0005 λ_g. Incidentally, an accuracy of this magnitude implies that the limitation in the accuracy of equivalent circuit parameters lies not in the electrical measurement but rather in the mechanical measurement required to locate the reference planes. It is desirable, as indicated in the above procedure, to determine the first-approximation values as accurately as possible by averaging a number of determinations. The extra effort hereby required is more than offset by the avoidance of the need for plotting more than one error curve. With the determination of γ, D_0, and S_0 relative to the chosen reference planes, the impedance parameters of a T-type equivalent circuit for the waveguide discontinuity follow from (9) and (10). The admittance parameters of a π-type equivalent circuit follow from (13) and (10) with Z replaced by Y.

(b) Six-Terminal Structures

The measurement of the equivalent circuit parameters of a six-terminal waveguide structure of the type shown in Fig. 2 consists basically in the reduction of the six-terminal structure to a four-terminal structure by placement of a known terminating reactance in one of the waveguides. In the case of the magnetic plane T, it is evident from Fig. 2(b) that the placement of an infinite impedance or quarter-wavelength line at the reference plane T_2 reduces the structure to a four-terminal network between the reference planes T_1 and T_3. The circuit parameters of the reduced four-terminal network are seen to be

$$a = -j\frac{Z_{11}}{Z_1}, \qquad c = -j\frac{Z_{33}}{Z_3}, \quad \text{and}$$
$$b = \frac{Z_{11}}{Z_1}\frac{Z_{33}}{Z_3} - \frac{Z_{13}^2}{Z_1 Z_3}. \tag{19}$$

The circuit parameters of this four-terminal structure are found by plotting a curve of D versus S relative to the reference planes T_1 and T_3 and analysis of the data for γ, D_0, and S_0 as described above. The circuit parameters of (19) then follow from (9) and (10). The remaining circuit parameter $Z_{11}-Z_{12}$ can be found as the negative of the reactance at T_2 required to reduce the power output at T_3 to zero, the power source being at T_1. As a check, an alternative measurement with the reactance at T_1 and the power source at T_2 should be made and averaged with the previous result. The last two measurements are subject to the criticism of being point measurements, but this is partially compensated by the fact that zero power measurements are highly accurate ones.

The equivalent circuit parameters of a general $2N$-terminal waveguide structure may be determined by a method similar to that sketched for the six-terminal network. In the $2N$-terminal case, known reactances are placed in all but two of the guides. The over-all structure is thereby reduced to a four-terminal structure which can be measured as above. The use of a suitable number of known reactances permits the determination of all unknown parameters of the $2N$-terminal equivalent circuit. In many cases, symmetries in the over-all structure suggest the type of known reactances to be employed for the purposes of both accuracy and simplification of the over-all equivalent circuit.

III. Equivalent Representations of Waveguide Structures by Reference-Plane Transformations

Since the choice of terminal planes for a waveguide structure is purely arbitrary, it is evident that, depending on the choice of terminal planes, there exists a variety of impedance representations and hence equivalent circuits for a waveguide discontinuity. Any one of these circuits completely characterizes the "far" field behavior. There exists no general criterion to determine which of the equivalent circuits is most appropriate. This ambiguous situation does not prevail for the case of lumped circuits because there is generally no ambiguity in the choice of terminals of a lumped circuit. Although, at low frequencies, there are, in general, many circuits equivalent to any given one, there is usually a "natural" one distinguished by having a minimum number of impedance elements of simple frequency variation. It is doubtful whether a corresponding "natural" circuit exists in general for a waveguide structure. In special cases, however, the same criterion of a minimum number of circuit parameters, simple frequency dependence, etc., can be employed to determine the best circuit representation.

For a four-terminal structure, a relatively simple means of determining an equivalent circuit representation at one set of reference planes from that at another is afforded by the tangent relation (5). One representation, mentioned previously in connection with (5), is that of an ideal transformer of transformation ratio $n^2 = -\gamma$ at the reference planes T_{10} and T_{20}. Other representations can also be obtained. For example, if the reference planes T_1 and T_2 of the general four-terminal network shown in Fig. 3 are shifted a distance d and s *away* from the junction to reference planes T_1' and T_2', the tangent relation relative to the new reference planes may be written as

$$\tan 2\pi[(D-d)-(D_0-d)] = \gamma \tan 2\pi[(S-s)-(S_0-s)]. \tag{20}$$

By comparison of (5) and (20), it is evident that parameters α', β', γ' relative to the new terminals are given by

$$\alpha' = \tan 2\pi(D_0-d) = \frac{\alpha-\alpha_0}{1+\alpha\alpha_0}$$
$$\beta' = \tan 2\pi(S_0-s) = \frac{\beta-\beta_0}{1+\beta\beta_0} \tag{21}$$
$$\gamma' = \gamma$$

where

$$\alpha_0 = \tan 2\pi D, \qquad \beta_0 = \tan 2\pi s. \tag{21a}$$

At the new terminals, the equivalent circuit parameters a', b', and c' are given by (10) with all quantities primed. The insertion therein of α', β', γ' from (21) and substitution for α, β, γ in terms of a, b, c, as given by (10) then yield the fundamental transformation equations

$$a' = \frac{a+\alpha_0+\beta_0 b-\alpha_0\beta_0 c}{1-\alpha_0 a-\beta_0 c-\alpha_0\beta_0 b} \tag{22a}$$

$$c' = \frac{c+\alpha_0 b+\beta_0-\alpha_0\beta_0 a}{1-\alpha_0 a-\beta_0 c-\alpha_0\beta_0 b} \tag{22b}$$

$$b' = \frac{b - \alpha_0 c - \beta_0 a - \alpha_0\beta_0}{1 - \alpha_0 a - \beta_0 c - \alpha_0\beta_0 b} \tag{22c}$$

for the relation between parameters of the $T(\pi)$ equivalent circuit at the reference planes $T_1'T_2'$ and that of the $T(\pi)$ at T_1T_2. This relation is also valid if a', b', c' refer to a $(\pi)T$ representation at $T_1'T_2'$ and a, b, c to $aT(\pi)$ at T_1T_2, provided in this case that

$$\alpha_0 = -\cot 2\pi d, \quad \beta_0 = -\cot 2\pi s. \tag{22d}$$

To illustrate the use of (22), let it be required to find the shift s of the output reference plane so as to make the resulting equivalent circuit pure shunt. Since in this case $b'=0$, it follows from (22c) that

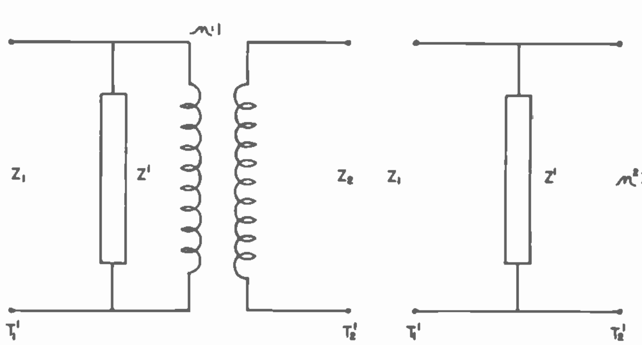
$$\beta_0 = \frac{b - \alpha_0 c}{a + \alpha_0} = \tan 2\pi s \tag{23}$$

gives the desired shift. The parameters of the "shifted" equivalent circuit are, on substitution of (23) into (22),

$$\begin{aligned} a' &= \frac{(\alpha_0 + a)^2 + (\alpha_0 c - b)^2}{(\alpha_0 + a)(1 - a\alpha_0) + (\alpha_0 c - b)(c + \alpha_0 b)}, \\ &= -\frac{jZ'}{Z_1} \\ \frac{a'}{c'} &= \frac{(\alpha_0 + a)^2 + (\alpha_0 c - b)^2}{(1 + \alpha_0^2)(b + ac)} = n^2\frac{Z_2}{Z_1}, \end{aligned} \tag{24}$$

where it is to be noted that α_0 may be chosen arbitrarily. Special values for α_0 of importance are $\alpha_0 = 0$ or $\alpha_0 = \beta_0$.

The new circuit can be schematically represented as in Fig. 6(a), which is a combination of an impedance Z' and an ideal transformer of turns ratio n. The circuit joins together transmission lines of characteristic impedance Z_1 and Z_2, representing the input and output waveguides. The use of an ideal transformer may be avoided by changing the characteristic impedance of the output line to n^2Z_2 as in Fig. 6(b). In addition to the above, many other equivalent circuit representations of a four-terminal waveguide structure can be readily evaluated by employing reference plane shifts d and s other than those illustrated above.



(a) (b)

Fig. 6—Equivalent representations of a shunt structure.

(a) *Transformation of Six-Terminal Structures*

The determination of equivalent representations of six-terminal waveguide structures is based on a consideration of the four-terminal networks that compose the over-all equivalent network. For the case of symmetrical magnetic-plane tee structures of the type shown in Fig. 2, it is apparent that a large variety of equivalent circuit representations can be obtained by shifting reference planes. This shifting is considerably simplified if the waveguide structure possesses geometrical symmetries. In such cases, the over-all structure can be readily reduced to a number of four-terminal structures for which the desired reference plane shifts can be effected by the methods described in the preceding section. This procedure will now be illustrated for the case of the magnetic-plane tee shown in Fig. 2.

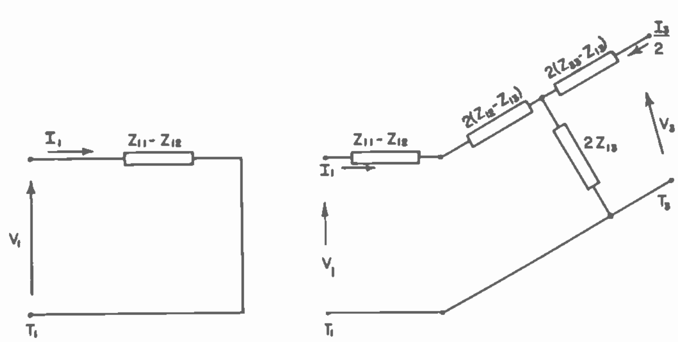
If the arbitrary currents impressed on the network shown in Fig. 2(b) are chosen in the antisymmetric manner $I_1 = -I_2$, $I_3 = 0$, the network equations (3) reduce to

$$\begin{aligned} V_1 = -V_2 &= (Z_{11} - Z_{12})I_1 \\ V_3 &= 0 \end{aligned} \tag{25}$$

or, if they are chosen in the symmetric manner $I_1 = +I_2$, (3) reduce to

$$\begin{aligned} V_1 = V_2 &= (Z_{11} + Z_{12})I_1 + 2Z_{13}\frac{I_3}{2} \\ V_3 &= 2Z_{13}I_1 + 2Z_{22}\frac{I_3}{2}. \end{aligned} \tag{26}$$

The reduced network equations (25) and (26) are seen to be descriptive of the circuits shown in Figs. 7(a) and (b), respectively. These two circuits result from the placement of a short or open circuit, respectively, at the electrical center of the equivalent circuit shown in Fig. 2(b).



(a) (b)

Fig. 7—Bisections of equivalent network for *H*-plane tee. (a) Antisymmetric case, and (b) symmetric case.

The reduction of the over-all network to these relatively simple component circuits follow (by bisection) from the symmetry of the original structure. Geometrical symmetry implies that antisymmetric excitation at T_1 and T_2 (Fig. 2(a)) will produce an electric field distribution antisymmetric about the symmetry plane T; hence, for this excitation, the transverse electric field at T is 0. Correspondingly, symmetrical excitation produces an electric field distribution symmetrical about T; hence, in the air space, the electric field at T is a maximum or equivalently the magnetic field transverse to T is 0. Thus, for antisymmetric excitation, the structure in Fig. 2(a) has a short circuit (electric wall) at T, and, correspondingly, for symmetric excitation, there is an open circuit (magnetic wall) at T. Since, in the former case, the dominant mode cannot be propagated in guide (3), the equivalent circuit is seen to be of the two-terminal type indicated in Fig. 7(a).

The reduced circuits shown in Figs. 7(a) and (b) are equivalent to the circuit indicated in Fig. 2(b) in the sense that the one follows from the other, and conversely. This equivalence may be usefully employed in the determination of the various equivalent circuits that result from the shift of the terminal planes from T_1, T_2, T_3 to different locations T_1', T_2', T_3'. The simplification obtained in treating reference-plane transformations of two- or four-terminal networks rather than of six-terminal networks should be apparent. For example, if the reference plane T_1 in Fig. 7(a) is shifted to T_1' a distance d in wavelengths *away* from the junction such that

$$\tan 2\pi d = j\,\frac{(Z_{11} - Z_{12})}{Z_1} = \alpha_0, \qquad (27)$$

then at the new reference plane, T_1', $Z_{11}' - Z_{12}' = 0$. Thus the new equivalent circuit for the antisymmetrical case is simply a short circuit. By the reasoning of (20) to (24) it follows that, if in addition to the above shift in T_1 the reference plane T_3 in Fig. 7(b) is moved a distance s, in wavelengths, *away* from the junction such that

$$\tan 2\pi s = \frac{b - \alpha_0 c}{a + \alpha_0} = \beta_0 \qquad (28)$$

where

$$a = -j\,\frac{(Z_{11} + Z_{12})}{Z_1}, \qquad c = -j\,\frac{2Z_{33}}{Z_2},$$
$$b = \frac{(Z_{11} + Z_{12})}{Z_1}\,\frac{(2Z_{33})}{Z_2} - \frac{(2Z_{13})^2}{Z_1 Z_2}, \qquad (29)$$

then at the new reference planes, T_1' and T_3', the equivalent circuit of Fig. 7(b) becomes a pure shunt circuit of the type indicated in Fig. 6. The circuit parameters of the new circuit can be obtained from (24) by use of (29).

In summary, it is seen that the reduced circuits indicated in Figs. 7(a) and (b) become, at the new terminals, T_1', T_2', T_3', those shown in Figs. 8(a) and (b). The indicated shunt impedance has the value $2Z'$ instead of Z' as employed in (24). The characteristic impedances rather than the new voltages and currents are indicated at the terminal planes. The over-all circuit, composed by a process inverse to that employed in obtaining the reduced circuits, is then that shown in Fig. Fig. 8(c). This simple circuit rather than its equivalent in Fig. 2(b) is often advantageously employed for the representation and measurement of the electrical performance of the given waveguide structure. The latter, however, is more convenient for the theoretical determination of the circuit parameters.

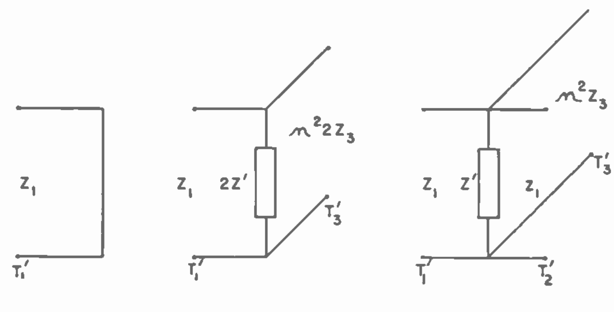


Fig. 8—Composition of shifted equivalent network for *H*-plane tee. (a) Shifted antisymmetric case; (b) shifted symmetric case; and (c) shifted composite network.

The above-illustrated technique of transformation of reference planes to obtain simple equivalent circuits can also be employed in the case of a $2N$-terminal circuit. The essence of this method is the reduction of the original $2N$-terminal network to a number of four- (or less) terminal networks for which the transformations can be readily effected. As in the case above, this reduction can be obtained simply if there exist certain symmetries in the original network.

Acknowledgment

This paper is based on part of a thesis, "Coupling of Waveguides by Small Apertures," submitted in partial fulfillment of the degree of doctor of electrical engineering at the Polytechnic Institute of Brooklyn, and was prepared in connection with Watson Laboratory Radiation Contract W-28-099-ac-146 at the Microwave Research Institute.

The Radiation Resistance of End-Fire and Collinear Arrays*

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***Summary.*—Expressions for the radiation resistances of end-fire and collinear arrays of half-wave dipoles are obtained in terms of circular functions in a form convenient for computation. No mathematical approximations except for a Fourier representation[1] of the field of a single half-wave dipole are used. The first integral theorem of Sonine[2] and an integral representation of the Bessel function due to Hansen[3] are involved in the integration of the normal component of Poynting's vector.**

Results computed from the new formula for the radiation resistance of an *n*-element parallel array in which the spacings and successive phasings of the dipole elements are 180 degrees (bilateral end-fire) agree closely with those of Pistolkors,[4] who used Brillouin's e.m.f. method; they are a little less than the figures of Bontsch-Bruewitsch,[5] who numerically integrated Poynting's vector. Calculations for the radiation resistance of an *n*-element collinear array using the new formula are compared with those of Bontsch-Bruewitsch, with which they are in satisfactory agreement. The new formula is also used to compute the radiation resistance of an *n*-element unilateral end-fire array (i.e., an *n*-element parallel array in which the spacings and successive phasings of the dipole elements are 90 degrees).

Introduction and Comparison of Results

In his patent Campbell[6] has calculated and plotted the radiation patterns of rectilinear arrays composed of 16 elements for spacings from 0 to 4 wavelengths in steps of one-eighth wavelength and successive phasings from 0 to one-half period in steps of one-eighth period. From these patterns it is seen that, when the elements are spaced one-half wavelength apart and successively phased one-half period, a bilateral end-fire is obtained. By reducing the spacing to one-quarter wavelength and the phasing to one-quarter period, a unilateral end-fire is obtained.

The radiation resistance of bilateral end-fire arrays has been calculated by Pistolkors[4] using the e.m.f. method for arrays having 2, 3, 4, 5, 6, and 7 elements. Bontsch-Bruewitsch[5] has calculated the radiation resistances of bilateral arrays by numerically integrating Poynting's vector for arrays consisting of 2, 3, 4, and an infinite number of elements. Table I shows the results of Pistolkors (P), Bontsch-Bruewitsch (BB), and those of this paper (PK), the last named computed from (26).

TABLE I

Average Radiation Resistance* of Bilateral Array

Number of Elements	P	BB	PK
2	85.7 ohms	88 ohms	82.30 ohms
3	92.5	95	87.72
4	96.8	100	91.04
5	99.8		93.30
6	102.1		94.95
7	103.9		96.22
Infinite		120	

* Average radiation resistance means the total radiation resistance divided by the number of elements: (R_0^e/n).

The radiation resistance of n collinear dipoles has been calculated by Bontsch-Bruewitsch,[5] who obtained the following formula:

$$R = (-1)^{n-1}60\left[\overset{n\pi}{\underset{0}{S}} - 4 \overset{(n-1)\pi}{\underset{0}{S}} + \overset{(n-2)\pi}{\underset{0}{8S}} \cdots \right] \quad (1)$$

where

$$\overset{n\pi}{\underset{0}{S}} = \int_0^{m\pi} \frac{\sin^2 \mu}{\mu} d\mu. \quad (2)$$

The results obtained from (1) for $n=1$, 2, 3, 4, and 5 and from the new formula (38) are shown in Table II.

TABLE II

Average Radiation Resistance* of Collinear Arrays

Number of elements	BB	PK
$n=1$		71.44 ohms
2	98 ohms	93.15
3	103	96.77
4	106	99.78
5	108	101.05
6		102.18
7		102.82

* Average radiation resistance means the total radiation resistance divided by the number of elements: (R_0^e/n).

The radiation resistances of unilateral end-fire arrays computed from (26) for spacings and phasings of 90° are shown in Table III.

* Decimal classification: R325.113×R221. Original manuscript received by the Institute, January 21, 1948. The research reported in this document was made possible through support extended Cruft Laboratory, Harvard University, jointly by the Navy Department (Office of Naval Research) and the Signal Corps, U. S. Army, under Contract N5ori-76, T.O.I.

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[6] G. A. Campbell, U. S. Patent No. 1, 783, 522.

TABLE III

Average Radiation Resistance* of Unilateral End-Fire Arrays

Number of elements	PK
2	71.44 ohms
3	78.68
4	82.30
5	85.55
6	87.72
7	89.62

* Average radiation resistance means the total radiation resistance divided by the number of elements: (R_0^e/n).

Calculation of the Radiation Resistance of End-Fire Arrays

In the derivation of the new formulas for the radiation resistance, it is tacitly assumed that changes in spacing and phasing between the dipoles have a negligible effect upon the current distribution in the individual dipoles. This is a good approximation for center-driven half-wave dipoles for all spacings. (It is a poor approximation for full-wave dipoles.)

The total radiated power is obtained by integrating the normal component of the Poynting vector S over a large sphere of radius R. If W is the total radiated power in watts,

$$W = \int_0^{2\pi}\int_0^{\pi} SR^2 \sin\theta\cdot d\theta\cdot d\phi$$
$$= \frac{30I_0^2}{2\pi}\int_0^{2\pi}\int_0^{\pi} V^2(\theta)\cdot A^2(\theta,\phi)\cdot\sin\theta\cdot d\theta\cdot d\phi \quad (3)$$

where $V(\theta)$ is the field factor of a single dipole, $A(\theta, \phi)$ is the array factor, and I_0 is the current amplitude at a loop position. They are contained explicitly in the following formula for the Poynting vector:

$$S = \frac{30I_0^2}{2\pi R^2}\left\{\frac{\cos\left(\frac{\pi}{2}\cdot\cos\theta\right)}{\sin\theta}\cdot\frac{\sin n\left(\pi\frac{s}{\lambda}\sin\theta\cos\phi+\pi\frac{s}{\lambda}\right)}{\sin\left(\pi\frac{s}{\lambda}\sin\theta\cos\phi+\pi\frac{s}{\lambda}\right)}\right\}^2. \quad (4)$$

In this expression, n is the number of half-wave dipoles in the array, s is the uniform spacing of the radiators, R is the radial distance from the center of the array to the point of calculation, and θ and ϕ are the polar and azimuthal angles, respectively. The quantity in brackets is the product of the two functions $V(\theta)$ and $A(\theta, \phi)$.

$$V(\theta) \equiv \frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\sin\theta}, \quad A(\theta,\phi) \equiv \frac{\sin ny}{\sin y} \quad (5)$$

where

$$y = \pi\frac{s}{\lambda}\sin\theta\cdot\cos\phi + \pi\frac{s}{\lambda} \equiv K_1\cos\phi + K_2. \quad (6)$$

In order to integrate the square of the array factor, it is expanded in a series of cosine terms and integrated term by term. Since the series contains only a finite number of terms, no difficulty arises in the term-by-term integration.

$$A^2(\theta,\phi) = \frac{\sin^2 ny}{\sin^2 y} = n + \sum_{r=2}^{2n-2}(2n-r)\cos ry \quad (7)$$

where $r=2, 4, 6, 8, \cdots$ even integer. Now, integrate both sides of (7) with respect to ϕ:

$$\int_0^{2\pi} A^2(\theta,\phi)d\phi$$
$$= \int_0^{2\pi} nd\phi + \sum_{r=2}^{2n-2}(2n-r)\int_0^{2\pi}\cos(ry)\cdot d\phi. \quad (8)$$

Hansen's[3] integral representation of a Bessel function is

$$\int_0^{2\pi}\cos(ry)d\phi = \int_0^{2\pi}\cos r(K_1\cos\phi+K_2)d\phi$$
$$= 2J_0(rK_1)\cos(rK_2). \quad (9)$$

Therefore, the integral of (7) with respect to ϕ is

$$\int_0^{2\pi} A^2(\theta,\phi)d\phi = 2\pi n + \sum_{r=2}^{2n-2}(2n-r)$$
$$\cdot 2\pi J_0(rK_1)\cos(rK_2) = H(\theta). \quad (10)$$

Note that each term on the right is a function only of the polar angle θ. It is represented by $H(\theta)$.

The integral representation of W in (3) now becomes

$$W = \frac{30I_0^2}{2\pi}\int_0^{\pi} V^2(\theta)\cdot H(\theta)\sin\theta d\theta. \quad (11)$$

Introduction of the Fourier approximation[1]

$$V(\theta) \doteq 0.945\sin\theta \quad (12)$$

in (11) gives

$$W = \frac{30I_0^2}{2\pi}\int_0^{\pi}(0.945)^2\cdot H(\theta)\sin^3\theta\cdot d\theta. \quad (13)$$

$H(\theta)\sin^3\theta$ is a finite series, each term of which must be integrated with respect to θ:

$$\int_0^{\pi} H(\theta)\sin^3\theta d\theta = 2\pi n\int_0^{\pi}\sin^3\theta d\theta$$
$$+ 2\pi\sum_{r=2}^{2n-2}(2n-r)\cdot\cos(rK_2)\int_0^{\pi} J_0(rK_1)\sin^3\theta d\theta.$$

The next task is to evaluate the integral

$$\int_0^{\pi} J_0(rK_1)\sin^3\theta\cdot d\theta. \quad (14)$$

From symmetry considerations of the integrand, this may be rewritten in the following way:

$$\int_0^{\pi} J_0(rK_1)\sin^3\theta\cdot d\theta = 2\int_0^{\pi/2} J_0\left(r\pi\frac{s}{\lambda}\sin\theta\right)\sin^3\theta\cdot d\theta. \quad (15)$$

Since $\sin^2\theta = 1-\cos^2\theta$, the integral (15) is the difference of two integrals of which each is in Sonine[2] form. Sonine's first integral[2] is given by

$$\int_0^{\pi/2} J_\nu(Z\sin\theta)\cdot\cos^{2\mu+1}\theta\cdot\sin^{\nu+1}\theta d\theta = 2^\mu\Gamma(\mu+1)\frac{J_{\nu+\mu+1}(Z)}{Z^{\mu+1}}. \quad (16)$$

With $\mu=-\frac{1}{2}$ and $\nu=0$ and substituting $r\pi/s\lambda$ for Z, the result is

$$\int_0^{\pi/2} J_0\left(r\pi\frac{s}{\lambda}\sin\theta\right)\sin\theta d\theta = \frac{\Gamma(\frac{1}{2})J_{1/2}\left(r\pi\frac{s}{\lambda}\right)}{\sqrt{2}\sqrt{r\pi\frac{s}{\lambda}}}. \quad (17)$$

Similarly, if with $\mu=\frac{1}{2}$ and $\nu=0$ and substituting $r\pi(s/\lambda)$ for Z,

$$\int_0^{\pi/2} J_0\left(r\pi\frac{s}{\lambda}\sin\theta\right)\cos^2\theta\cdot\sin\theta\cdot d\theta = \frac{\sqrt{2}\,\Gamma(\frac{3}{2})J_{3/2}\left(r\pi\frac{s}{\lambda}\right)}{\left(r\pi\frac{s}{\lambda}\right)^{3/2}}, \quad (18)$$

therefore,

$$2\int_0^{\pi/2} J_0\left(r\pi\frac{s}{\lambda}\sin\theta\right)\sin^3\theta\cdot d\theta = \frac{2\Gamma(\frac{1}{2})J_{1/2}\left(r\pi\frac{s}{\lambda}\right)}{\sqrt{2}\sqrt{r\pi\frac{s}{\lambda}}} - \frac{2\sqrt{2}\,\Gamma(\frac{3}{2})J_{3/2}\left(r\pi\frac{s}{\lambda}\right)}{\left(r\pi\frac{s}{\lambda}\right)^{3/2}}. \quad (19)$$

The expression for the radiated power then takes the form:

$$W = \frac{30I_0^2}{2\pi}(0.945)^2\left[\frac{8\pi n}{3} + 2\pi\sum_{r=2}^{2n-2}(2n-r)\cdot\cos(rK_2)\cdot\left\{\frac{\sqrt{2}\,\Gamma(\frac{1}{2})J_{1/2}\left(r\pi\frac{s}{\lambda}\right)}{\sqrt{r\pi\frac{s}{\lambda}}} - \frac{2\sqrt{2}\,\Gamma(\frac{3}{2})J_{3/2}\left(r\pi\frac{s}{\lambda}\right)}{\left(r\pi\frac{s}{\lambda}\right)^{3/2}}\right\}\right] \quad (20)$$

and the external or radiation resistance $R_0^e = 2W/I_0^2$ becomes

$$R_0^e = \frac{60}{2\pi}(0.945)^2\left(\frac{8\pi}{3}n + 2\pi\sum_{r=2}^{2n-2}(2n-r)\cos(rK_2)\cdot\left\{\frac{\sqrt{2}\,\Gamma(\frac{1}{2})J_{1/2}\left(r\pi\frac{s}{\lambda}\right)}{\sqrt{r\pi\frac{s}{\lambda}}} - \frac{2\sqrt{2}\,\Gamma(\frac{3}{2})J_{3/2}\left(r\pi\frac{s}{\lambda}\right)}{\left(r\pi\frac{s}{\lambda}\right)^{3/2}}\right\}\right]. \quad (21)$$

This expression involves Bessel functions with fractional indexes which are not convenient for computation. It is possible to transform them into circular functions using

$$J_{1/2}\left(r\pi\frac{s}{\lambda}\right) = \sqrt{\frac{2}{\pi}}\frac{\sin\left(r\pi\frac{s}{\lambda}\right)}{\sqrt{r\pi\frac{s}{\lambda}}} \quad (22)$$

and

$$J_{3/2}\left(r\pi\frac{s}{\lambda}\right) = \sqrt{\frac{2}{\pi}}\left\{\frac{\sin\left(r\pi\frac{s}{\lambda}\right)}{\left(r\pi\frac{s}{\lambda}\right)^{3/2}} - \frac{\cos\left(r\pi\frac{s}{\lambda}\right)}{\sqrt{r\pi\frac{s}{\lambda}}}\right\}. \quad (23)$$

Evidently,

$$\frac{J_{1/2}\left(r\pi\frac{s}{\lambda}\right)}{\sqrt{r\pi\frac{s}{\lambda}}} = \sqrt{\frac{2}{\pi}}\frac{\sin\left(r\pi\frac{s}{\lambda}\right)}{r\pi\frac{s}{\lambda}}, \quad (24)$$

and

$$\frac{J_{3/2}\left(r\pi\frac{s}{\lambda}\right)}{\left(r\pi\frac{s}{\lambda}\right)^{3/2}} = \sqrt{\frac{2}{\pi}}\left\{\frac{\sin\left(r\pi\frac{s}{\lambda}\right)}{\left(r\pi\frac{s}{\lambda}\right)^3} - \frac{\cos\left(r\pi\frac{s}{\lambda}\right)}{\left(r\pi\frac{s}{\lambda}\right)^2}\right\}. \quad (25)$$

Since $\Gamma(\frac{1}{2}) = \sqrt{\pi}$ and $\Gamma(3/2) = \frac{1}{2}\sqrt{\pi}$, the final expression for the radiation resistance is

$$R_0{}^e = \frac{60}{2\pi}(0.945)^2\left[\frac{8\pi n}{3} + 4\pi\sum_{r=2}^{2n-2}(2n-r)\right.$$
$$\left.\cdot\cos(rK_2)\Lambda\left(r\pi\frac{s}{\lambda}\right)\right] \quad (26)$$

where

$$\Lambda\left(r\pi\frac{s}{\lambda}\right) = \frac{\sin\left(r\pi\frac{s}{\lambda}\right)}{r\pi\frac{s}{\lambda}} - \frac{\sin\left(r\pi\frac{s}{\lambda}\right)}{\left(r\pi\frac{s}{\lambda}\right)^3}$$
$$+ \frac{\cos\left(r\pi\frac{s}{\lambda}\right)}{\left(r\pi\frac{s}{\lambda}\right)^2}. \quad (27)$$

This formula is readily evaluated numerically. The results are shown in Tables I, III, and IV.

Calculation of the Radiation Resistance of Collinear Arrays

The radiation resistance of an n-element collinear antenna is given by the well-known integral:

$$R_0{}^e = 60\int_0^\pi \frac{\cos^2\left(\frac{\pi}{2}\cos\theta\right)}{\sin^2\theta}\cdot\frac{\sin^2 n\left(\frac{\pi}{2}\cos\theta\right)}{\sin^2\left(\frac{\pi}{2}\cos\theta\right)}$$
$$\cdot\sin\theta\cdot d\theta. \quad (28)$$

With (12), this becomes

$$R_0{}^e = 60(0.945)^2\int_0^\pi \frac{\sin^2 n\left(\frac{\pi}{2}\cos\theta\right)}{\sin^2\left(\frac{\pi}{2}\cos\theta\right)}\cdot\sin^3\theta\cdot d\theta. \quad (29)$$

In order to solve this integral, it is convenient to expand

$$\frac{\sin^2 ny}{\sin^2 y}:$$

$$\frac{\sin^2 ny}{\sin^2 y} = n + \sum_{r=2}^{2n-2}(2n-r)\cos ry \quad (30)$$

where $y=(\pi/2)\cos\theta$ and $r=2, 4, 6, 8 \cdots$ even integer. With (30), the expression for radiation resistance takes the form:

$$R_0{}^e = 60(0.945)^2\left\{n\int_0^\pi \sin^3\theta d\theta\right.$$
$$\left.+ \sum_{r=1}^{2n-2}(2n-r)\int_0^\pi \cos\left(r\frac{\pi}{2}\cos\theta\right)\sin^3\theta\cdot d\theta\right]. \quad (31)$$

The first integral is immediately integrable. It is

$$\int_0^\pi \sin^3\theta d\theta = \tfrac{4}{3}. \quad (32)$$

The second integral can be evaluated by Hankel's integral theorem:

$$\int_0^\pi \cos(Z\cos\theta)\cdot\sin^{2\nu}\theta\cdot d\theta = \frac{J_\nu(Z)\Gamma(\frac{1}{2})\Gamma(\nu+\frac{1}{2})}{(\frac{1}{2}Z)_\nu}. \quad (33)$$

This evaluation holds for $\nu > -\frac{1}{2}$. With $2\nu=3$ and $Z=r(\pi/2)$, and recalling that the gamma functions $\Gamma(\frac{1}{2})$ and $\Gamma(3/2+\frac{1}{2})$ have the values $\sqrt{\pi}$ and 1, respectively, (33) becomes

$$\int_0^\pi \cos\left(r\frac{\pi}{2}\cos\theta\right)\sin^3\theta\cdot d\theta$$
$$= \frac{J_{3/2}\left(r\frac{\pi}{2}\right)\cdot\sqrt{\pi}\cdot 2\sqrt{2}}{\left(r\frac{\pi}{2}\right)^{3/2}}. \quad (34)$$

It is well known that

$$\frac{J_{3/2}\left(r\frac{\pi}{2}\right)}{\left(r\frac{\pi}{2}\right)^{3/2}} = \sqrt{\frac{2}{\pi}}\left\{\frac{\sin\left(r\frac{\pi}{2}\right)}{\left(r\frac{\pi}{2}\right)^3} - \frac{\cos\left(r\frac{\pi}{2}\right)}{\left(r\frac{\pi}{2}\right)^2}\right\} \quad (35)$$

Since r is always an even integer, $\sin[r(\pi/2)]=0$, and

$$\frac{J_{3/2}\left(r\frac{\pi}{2}\right)}{\left(r\frac{\pi}{2}\right)^{3/2}} = -\sqrt{\frac{2}{\pi}}\,\frac{\cos\left(r\frac{\pi}{2}\right)}{\left(r\frac{\pi}{2}\right)^2}. \quad (36)$$

Hence,

$$\int_0^\pi \cos\left(r\frac{\pi}{2}\cos\theta\right)\sin^3\theta\cdot d\theta = -4\frac{\cos\left(r\frac{\pi}{2}\right)}{\left(r\frac{\pi}{2}\right)^2}. \quad (37)$$

If this result is substituted in (31) with (32), the formula for $R_0{}^e$ in ohms is obtained:

$$R_0{}^e = 60(0.945)^2\left\{\frac{4n}{3} - 4\sum_{r=2}^{2n-2}(2n-r)\frac{\cos\frac{r\pi}{2}}{\left(\frac{r\pi}{2}\right)^2}\right\}. \quad (38)$$

For purposes of numerical calculation this formula is much simpler than (1) previously derived by Bontsch-Bruewitsch. The results are compared in Table II.

Calculation of the Radiation Resistance of a Broadside Array

The general radiation resistance formula

$$R_0{}^e = \frac{60}{2\pi}(0.945)^2\left[\frac{8\pi n}{3} + 4\pi\sum_{r=2}^{2n-2}(2n-r)\cos(rK_2)\Lambda\left(r\pi\frac{s}{\lambda}\right)\right] \quad (26)$$

gives the radiation resistance of any parallel array consisting of center-fed half-wave dipoles, provided the spacing s between the elements is uniform and the phasing K_2 is uniformly progressive or zero.

The radiation resistance of a broadside array, $[s=(\lambda/2),\ K_2=0]$ is, therefore, given by the specialized case of (26):

$$R_0^e=\frac{60}{2\pi}(0.945)^2\left[\frac{8\pi n}{3}+4\pi\sum_{r=2}^{2n-2}(2n-r)\Lambda\left(r\frac{\pi}{2}\right)\right]. \qquad (39)$$

$$R_0^e=\frac{60}{2\pi}(0.945)^2\left[\frac{8\pi n}{3}-8\pi\sum_{r=2}^{2n-2}(2n-r)\Lambda\left(r\frac{\pi}{2}\right)\right]. \qquad (38)^7$$

The average, radiation resistances (R_0^e/n) are computed for $n=1, 2, 3, 5, 6, 7$ and shown in Table II.

In addition, a general formula (26) for the radiation resistance of any uniformly spaced (s) parallel array of half-wave dipoles with uniform progressive phasing (K_2), including zero, is derived.

$$R_0^e=\frac{60}{2\pi}(0.945)^2\left[\frac{8\pi n}{3}+4\pi\sum_{r=2}^{2n-2}(2n-r)\cos(rK_2)\Lambda\left(r\pi\frac{s}{\lambda}\right)\right] \qquad (26)$$

where

$$\Lambda\left(r\pi\frac{s}{\lambda}\right)=\frac{\sin\left(r\pi\frac{s}{\lambda}\right)}{\left(r\pi\frac{s}{\lambda}\right)}-\frac{\sin\left(r\pi\frac{s}{\lambda}\right)}{\left(r\pi\frac{s}{\lambda}\right)^3}+\frac{\cos\left(r\pi\frac{s}{\lambda}\right)}{\left(r\pi\frac{s}{\lambda}\right)^2}.$$

The radiation resistances of broadside arrays consisting of 2, 3, 4, 5, 6, and 7 elements are computed and shown in Table IV.

TABLE IV

AVERAGE RADIATION RESISTANCE* OF BROADSIDE ARRAYS

Number of elements	P	BB	PK
$n=2$	60.9 ohms		60.58 ohms
3	59.5		58.78
4	58.0		57.27
5	57.4		56.63
6	56.9		56.07
7	56.5		55.75
Infinite		56 ohms	

* Average radiation resistance means the total radiation resistance divided by the number of elements: (R_0^e/n).

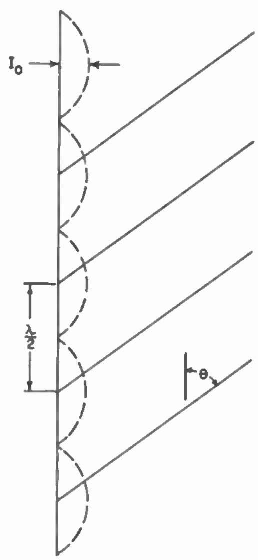

Fig. 1—Collinear array. Radiation resistance for n-element collinear array:

$$R_0^e=60(0.945)^2\left\{\frac{4n}{3}-4\sum_{r=2}^{2n-2}(2n-r)\frac{\cos\left(r\frac{\pi}{2}\right)}{\left(\frac{r\pi}{2}\right)^2}\right\}.$$

Fig. 2—Broadside end-fire. Radiation resistance for n-element broadside array:

$$R_0^e=\frac{60}{2\pi}(0.945)^2\left[\frac{8\pi n}{3}+4\pi\sum_{r=2}^{2n-2}(2n-r)\Lambda\left(r\frac{\pi}{2}\right)\right]$$

and

$$\Lambda\left(r\frac{\pi}{2}\right)\equiv\frac{\cos\left(r\frac{\pi}{2}\right)}{\left(r\frac{\pi}{2}\right)^2}.$$

Fig. 3—Unilateral end-fire. Radiation resistance for n-element unilateral array:

$$R_0^e=\frac{60}{2\pi}(0.945)^2\left[\frac{8\pi n}{3}+4\pi\sum_{r=2}^{2n-2}(2n-r)\cos\left(r\frac{\pi}{4}\right)\Lambda\left(r\frac{\pi}{4}\right)\right]$$

and

$$\Lambda\left(r\frac{\pi}{4}\right)\equiv\frac{\sin\left(r\frac{\pi}{4}\right)}{\left(r\frac{\pi}{4}\right)}-\frac{\sin\left(r\frac{\pi}{4}\right)}{\left(r\frac{\pi}{4}\right)^3}+\frac{\cos\left(r\frac{\pi}{4}\right)}{\left(r\frac{\pi}{4}\right)^2}.$$

CONCLUSIONS

A formula (38) is derived for the radiation resistance of a collinear array consisting of n in-phase half-wave dipoles spaced one half wavelength between centers (Fig. 1).

[7] This equation equals (38) found in an earlier part of this paper. It has been written in this form to place in evidence its similarity to (26).

By giving K_2 and s appropriate values, the average radiation resistances of broadside, unilateral end-fire, and bilateral end-fire arrays with 2, 3, 4, 5, 6, and 7 elements (Figs. 2, 3, 4) are computed and shown in Tables I, III, and IV.

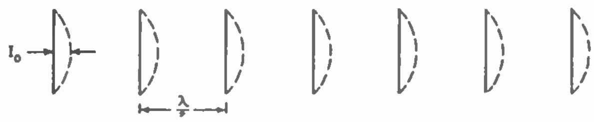

Fig. 4—Bilateral end-fire. Radiation resistance for n-element bilateral array:

$$R_0^* = \frac{60}{2\pi}(0.945)^2\left[\frac{8\pi n}{3} + 4\pi\sum_{r=2}^{2n-2}(2n-r)\cos\left(r\frac{\pi}{2}\right)\Lambda\left(r\frac{\pi}{2}\right)\right]$$

and

$$\Lambda\left(r\frac{\pi}{2}\right) \equiv \frac{\cos\left(r\frac{\pi}{2}\right)}{\left(r\frac{\pi}{2}\right)^2}.$$

The values of K_2, s, and Λ used in the calculation are shown in Table V.

TABLE V

K_2*	s	Λ	Phase Difference in Periods	Nature of Pattern
$\pi/2$	$\lambda/2$	$\Lambda[r(\pi/2)]$	$\frac{1}{2}$	Bilateral end-fire
$\pi/4$	$\lambda/4$	$\Lambda[r(\pi/2)]$	$\frac{1}{4}$	Unilateral end-fire
0	$\lambda/2$	$\Lambda[r(\pi/2)]$	0	Broadside
r		$\Lambda[r(\pi/4)]$		$\Lambda[r(\pi/2)]$
2		0.3786		−0.1013
4		−0.1013		+0.02533
6		−0.2026		−0.01126
8		0.02533		+0.006333
10		0.1252		−0.004053
12		−0.01126		+0.002814

* K_2, according to (6), equals π times phase displacement measured in fractions of a period.

Acknowledgment

The authors acknowledge the aid of Miss M. L. Richardson, who performed all the calculations.

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

Wanamaker—Underwood and Underwood

Frank J. Bingley

Frank J. Bingley (A'34–M'36–SM'43) was born on November 13, 1906, in Bedford, England. Following his graduation from the University of London in 1927, Mr. Bingley was associated with Baird Television Ltd., London, and for two years following he was in charge of Baird's New York Laboratories, after which he joined the Philco Corporation as a television research engineer. He is now chief television engineer of Philco.

Under Mr. Bingley's direction, television station WPTZ at Wyndmoor, Pa., was designed and constructed in 1941. Mr. Bingley was instrumental in developing the Plane-O-Scope, a flat-surface picture tube which presents an undistorted picture, regardless of the angle from which it is viewed. Remote-pickup equipments in the Philadelphia area, a mobile unit for "on-the-spot" television shows, and the Philco radio relay for television between New York and Philadelphia are other developments instituted by Mr. Bingley.

Mr. Bingley is a director of the Television Broadcasters Association, and a member of the Franklin Institute. He has served as a member of several prominent television planning committees, notably those of RMA, the National Television Systems Committee, and the Radio Technical Planning Board. He is also a member of the Papers Review and Color Television Committees of I.R.E.

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Christopher P. Gadsden

Christopher P. Gadsden (M'45) was born in Charlotte, N. C., in 1920. He received the B.S. degree in electrical engineering from Tulane University in 1942. Immediately thereafter he joined the staff of the Radiation Laboratory at the Massachusetts Institute of Technology, where he remained through 1945. There he worked with the receiver group on the measurement and improvement of the noise figure of intermediate-frequency amplifiers. At the present time he is studying and teaching mathematics at Tulane University.

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For a photograph and biography of Ronold King, see page 244 of the February, 1948, issue of the Proceedings of the I.R.E.

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James E. Hacke, Jr., was born in 1920 at Essex, Iowa. He received the A.B. and M.S. degrees at the University of Georgia in 1940 and 1941, and has done graduate work in physics at Columbia University and The Pennsylvania State College.

From 1943 to 1946 Mr. Hacke worked in

James E. Hacke, Jr.

The Johns Hopkins University Applied Physics Laboratory, Silver Spring, Md., on analysis of quality-control and surveillance testing of the proximity fuze for artillery use. He has been employed since 1946 on basic research in ionosphere propagation of short waves at The Pennsylvania State College under contract with Watson Laboratories, Air Matériel Command. He is a member of the American Physical Society and of the Sigma Xi.

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Alan B. Macnee (A'45) was born on September 19, 1920, in New York, N. Y. He received the B.S. and M.S. degrees in electrical engineering from the Massachusetts Institute of Technology in 1943. From 1943 to 1946 he was a staff member in the receiver group at the M. I. T. Radiation Laboratory, specializing in the noise performance of intermediate-frequency amplifiers. Since 1946 he has held the position of assistant on the electrical engineering staff at M. I. T., engaged in research on electronic computation.

He is an associate member of Sigma Xi, and a member of Eta Kappa Nu.

Alan B. Macnee

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Nathan Marcuvitz (S'36–A'37) was born in Brooklyn, N. Y., on December 29, 1913. He was graduated from the Polytechnic Institute of Brooklyn, receiving the degrees of B.E.E. in 1935, M.E.E. in 1940, and D.E.E. in 1947.

From 1935 to 1936, Dr. Marcuvitz was a research fellow at the Polytechnic Institute. From 1936 to 1940, he was employed by the RCA Manufacturing Company, and did work on high-g_m vacuum tubes, iconoscopes, and orthicons. From 1940 to 1941 he held a research fellowship at Polytechnic Institute, and during 1941 to 1946 he did research on waveguides at the M.I.T. Radiation Laboratory. In 1946 he returned to the Polytechnic Institute as assistant professor of electrical engineering, and also as a research associate at the Microwave Research Institute. He is a member of the American Physical Society, Sigma XI, Tau Beta Pi, and Eta Kappa Nu.

Nathan Marcuvitz

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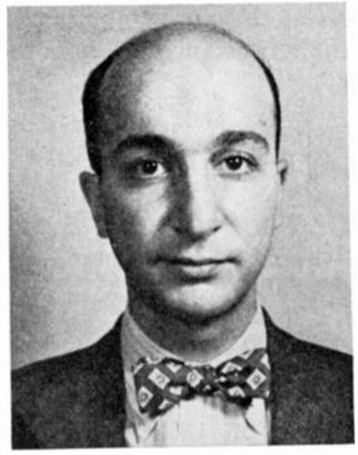
Charles H. Papas (S'41–A'42) was born in Troy, N. Y., on March 29, 1918. He received the B.S. degree in electrical engineering from the Massachusetts Institute of Technology in 1941. From 1941 to 1945 he was engaged in research on various problems in acoustics and electrodynamics for the Naval Ordnance Laboratory and the Bureau of Ships, Washington, D. C. Since 1945 Mr. Papas has been at Cruft Laboratory, Harvard University, where he is working on problems in electromagnetic theory. He is a member of the American Mathematical Society.



Charles H. Papas

❖

Henry Wallman (A'41) was born in New York, N. Y., in 1915. He received the Ph.D. degree in mathematics from Princeton University in 1937. From 1942 to 1946 he was in the receiver group of the Radiation Laboratory at the Massachusetts Institute of Technology, and was chiefly concerned with the design and transient analysis of wideband amplifiers, and noise investigations.

Before the war Dr. Wallman taught mathematics at the University of North Carolina and the University of Wisconsin. At present he is associate professor of mathematics at M. I. T. He is the co-author of a book on Topology, "Dimension Theory," and also co-editor of the forthcoming volume on "Vacuum Tube Amplifiers," of the Radiation Laboratory Series. Dr. Wallman is a member of the American Mathematics Society and Sigma Xi.

Henry Wallman

Institute News and Radio Notes

Board of Directors

March 25, 1948

Report of Committee on Professional Groups. Dr. W. L. Everitt, Chairman of the Committee on Professional Groups, presented to the Board the report of the Committee on Professional Groups, dated March 25, 1948. The Committee on Professional Groups held its first meeting on Monday, March 22, 1948, and at that time drew up a set of Bylaws. The Committee recommended the early adoption of a set of Bylaws substantially like those proposed. It also recommended the addition of a Committee on Professional Groups to the Standing Committees in the Bylaws of the Institute; the appointment of a Standing Committee on Professional Groups, constituted as outlined in the proposed Bylaw A, to supersede the ad-hoc Committee on Professional Groups making the report; and immediate publicity on the Professional Group System through the PROCEEDINGS and through the technical press. Dr. Everitt commented briefly on the details of the several recommendations, and the matter was placed before the meeting for discussion. Mr. Coleman inquired as to the possibility of the Group setup interfering with the operation of Sections. Dr. Everitt replied that the Group system could be of use to Sections and facilitate their operation rather than to hinder it, and was confirmed by Dr. Heising. After further discussion, Dr. Goldsmith moved that the Executive Committee be instructed to proceed in accordance with the recommendations of the March 25, 1948, memoranda submitted by the Chairman of the Committee on Professional Groups, and that the Constitution and Laws Committee be instructed to prepare such Bylaws and sample Constitution as may be needed in accordance therewith. (Unanimously approved.)

American Standards Association. Dr. Baker reported that an agreement had been reached with the American Standards Association whereby the A.S.A. will entirely eliminate any standardization work on its own initiative, and a plan had been proposed whereby bodies such as the I.R.E. and the RMA would submit their Standards to the Communication and Electronics Division of the A.S.A. Electrical Standards Committee, so that all I.R.E. or RMA Standards could be published as A.S.A. Standards at the same time they were published as I.R.E. or RMA Standards. Standards would be completely prepared and formulated by I.R.E. before going to A.S.A. for processing, and A.S.A. would stay completely out of the operational work. I.R.E. would always publish its own Standards, independently of A.S.A., but the plan would give A.S.A. the opportunity to act with dispatch on the Standards—within 60 to 90 days—before I.R.E. publishes them.

Joint Technical Advisory Committee (of RMA and I.R.E.). Dr. Baker discussed the following existing situations which require I.R.E. and RMA action and proposed their solution by the formation of a Joint Technical Advisory Committee:

Radio Technical Planning Board. Dr. Baker stated that in his opinion the RTPB should be disbanded. It has performed its function and only three committees are at all active. These are No. 6, Television; No. 7, Facsimile; and No. 13, Portable, Mobile, and Emergency Service Communications. These activities could be allocated to I.R.E. or RMA, or jointly to both. Dr. Sinclair, representative of I.R.E. on RTPB, confirmed Dr. Baker's statement.

Co-operation with F.C.C. Dr. Baker discussed two problems which Wayne Coy, chairman of the F.C.C., brought up in his speech at the President's Luncheon on Tuesday, March 23, during the National Convention. These were: (a) The necessity for action by industry with respect to radiation from television receivers. RMA has obtained Board approval to set Standards which will be distributed to the industry and sent to F.C.C. (b) The F.C.C. lacks information in regard to characteristics and equipment in the high frequencies from 270 to 1000 Mc. Dr. Baker suggested that some industry group should take over this problem, not making a monetary expenditure, but simply by getting the manufacturers together, accumulating all information available, finding out from industry to what extent it is able to build transmitters and design receivers within this frequency range.

Dr. Baker suggested that a procedure should be set up by the I.R.E. and RMA to take over the work of the three active RTPB Panels and the two other projects noted above. After discussion by the Board, it was decided that the best solution to the problems involved was to set up a Joint Technical Advisory Committee of the RMA and I.R.E., whose function would be to serve the F.C.C., to maintain contact with the F.C.C., and find out what information they want. Therefore, the following actions were taken on Dr. Baker's suggestions:

Dr. Goldsmith moved that there be formed, with the assent of the RMA Engineering Department, a joint Standing Committee of the RMA-I.R.E., to be known as the "Joint Technical Advisory Committee (of RMA and I.R.E.)." This committee will be authorized to initiate or to receive requests for technical and industrial information from Governmental bodies and to recommend to the RMA or I.R.E., or both, the establishment of corresponding individual working or task committees to assemble the desired information, this in turn to be transmitted to the Governmental group in question. Notice of the above action shall be promptly transmitted to the Chairman of the F.C.C. (Unanimously approved.)

Mr. Guy moved that the Executive Committee be authorized to appoint on an ad-hoc basis the I.R.E. portion of this joint committee and instruct them to begin function. (Unanimously approved.)

Mr. Hogan moved that it be resolved that the representative of I.R.E. on the RTPB Administrative Committee be instructed to report to that committee that the I.R.E. considers the work of the RTPB to have been substantially completed, that RMA and I.R.E. propose the formation of a Joint Technical Advisory Committee, which will render any further needed assistance to Government agencies, that the I.R.E. Board recommends the dissolution of the RTPB, and that the I.R.E. Board proposes to withdraw its financial support of RTPB. (Unanimously approved.)

Dr. Baker moved that the Joint Advisory Committee be instructed to consider working groups on Facsimile, Emergency Communications, and spectrum utilization. The characteristics and availability of equipment shall be prime portions of such studies, and immediate attention shall be particularly concentrated on spectrum utilization and equipment in the region of 250 to 1000 Mc. (Unanimously approved.)

Mr. S. L. Bailey moved that the Minutes referring to the establishment of the Joint Technical Advisory Committee be transmitted to the Constitution and Laws Committee, with a request that they prepare the proper Bylaws for the approval of the Board. (Unanimously approved.)

Committee on Professional Groups. Dr. Goldsmith moved that the recommendation of the Executive Committee that the Board accept the recommendation of the Planning Committee in which it desires to amend its report of November 12, 1947, to the extent of changing the name "Audio Group" to "Audio, Video and Acoustic Group," and adding the following names to the Committee: Howard A. Chinn, O. L. Angevine, Jr., A. A. Pulley, J. L. Hathaway, and J. E. Keister, be accepted, and that the request by W. L. Everitt, Chairman of the Committee on Professional Groups, for the appointment of two additional members to the Ohio State Broadcast Group, Lynne C. Smeby and Royal V. Howard, be approved. (Unaninously approved.)

New Committee on Planning. President Shackelford presented to the Board for consideration the following recommendation of the Executive Committee with regard to the re-organization of the Planning Committee:

> "The Executive Committee recommends to the Board that the Planning Committee be discharged and discontinued, and that a new committee be set up to make studies for the Board and recommend to the Board for consideration matters of long-term planning and policy development. The agenda for the new committee would be composed of such subjects referred to it by the Board, or which may originate from other sources.
>
> "It is suggested that the membership of the committee be of two classes; that one class consist of six members, serving three-year terms, two to be appointed each year, with the necessary short terms for the initiation of the committee. It is suggested that there be a second class of three members appointed for a term of one

year, one each to represent Institute Sections, Student Branches, and Regions.

"It is proposed that the membership of the committee be approximately 50 per cent members or recent members of the Board, and that reasonable geographical distribution be provided for.

"It is recommended that the membership of this committee be selected by the the Board upon recommendation of the President. The Chairman also would be named in the same manner."

Dr. Shackelford commented that the function of the above-outlined committee would definitely be the development of policy to enable the Board to have data available when it gives policy decisions; that there are matters of Institute policy which need resurveying because of the growth of the industry and of the Institute; that the committee should have enough continuity of membership to give continuity of policy and yet enough provision for the admission of new members to bring in new ideas; that the membership of the committee should consist not only of appointed members, but also of representatives of the various Institute special activities, such as Sections, Student Branches, and Regions, as noted above, and perhaps, also, Professional Groups, Editorial Policy, and Technical Committees.

After discussion by the Board, Dr. Sinclair moved that the present Planning Committee be discharged, with thanks for its work, and dissolved. (Unanimously approved.)

Dr. Terman moved that the Board instruct the Executive Committee to proceed to formulate the details of a plan of formation of a committee, such as had been outlined by Dr. Shackelford, with a rotating membership and representative membership, operating under a suitable name, to provide advice as to policy. (Unanimously approved.)

Dr. Terman moved that the President be empowered to appoint, with the approval of the Executive Committee, an ad-hoc committee to operate on an interim basis and carry out the functions of this advisory committee. (Unanimously approved.)

Mr. Guy moved that the Board instruct the Constitution and Laws Committee to draft the necessary Bylaws change to cover the formation and scope of the committee referred to in the two previous motions. (Unanimously approved.)

San Antonio Section. Dr. Sinclair moved that the petition of the San Antonio Section be accepted, and that the boundaries of the Section be set according to the map included with the petition. (Unanimously approved.)

M.K.S. Rationalized System of Measuring Units. Dr. Heising moved that the Board approve the Standards Committee recommendation of January 8, 1948, that the I.R.E. promote the general use of the m.k.s. rationalized system of measuring units. Planned methods of promotion will include an editorial on the m.k.s. system to be prepared by Chairman Schelkunoff of the Wave Propagation Committee for publication in the PROCEEDINGS. (Unanimously approved.)

Finance Committee. Mr. Hogan moved that the Board approve the recommendation of the Executive Committee that there be appointed a Finance Committee of three members to maintain continuous familiarity with the finances of the Institute and to make recommendations thereto from time to time as may seem desirable. (Unanimously approved.)

Institution of Radio Engineers (Australia). Dr. Goldsmith reported that a reciprocal arrangement has been concluded with the Institution of Radio Engineers (Australia), whereby any papers appearing in their journal become available for publication in the PROCEEDINGS OF THE I.R.E., without further notice, but with acknowledgment of their source, and conversely, papers appearing in the PROCEEDINGS become available for publication to the Institution of Radio Engineers (Australia).

Bylaw Section 89. Mr. Coleman moved that the following modified Bylaw Section 89 be adopted:

"Section 89—The Executive Secretary is authorized to accept orders received after April 1, 1948, for annual subscriptions to, or individual copies of, the PROCEEDINGS, at the following rates, including postage:

Annual Subscriptions

	U. S. and Canada	Other Countries
Individual non-members	$18.00	$19.00
Public Libraries	13.50	14.50
Colleges	13.50	14.50
Subscription Agencies	13.50	14.50
Institute members, additional subscriptions	9.00	10.00

Individual Copies

	U. S. and Canada	Other Countries
Individual non-members	$2.25	$2.35
Public Libraries	1.65	1.75
Colleges	1.65	1.75
Subscription Agencies	1.65	1.75
Institute members, additional copies	1.00	1.10

(Unanimously approved.)

NEW TABLES OF BESSEL FUNCTIONS

Of interest to nuclear technologists, as well as other design engineers and physicists, is the recent publication of extensive tables of the Bessel functions $Y_0(x)$, $Y_1(x)$, $K_0(x)$, and $K_1(x)$ in the region between 0 and 1. These tables, prepared by the National Bureau of Standards, are now available as a 71-page booklet, constituting the first in the new Applied Mathematics Series, which will include mathematical tables, manuals, and studies by the National Applied Mathematics Laboratories of the Bureau.

Because of the frequent need for numerical values of the Bessel functions in many physics and engineering problems, the tables have been computed at much closer intervals than previous tabulations of these functions, thus enabling the user to obtain almost the full accuracy of the table, over most of the range, by linear interpolation. Specifically, the tables give the values of $Y_0(x)$ and $Y_1(x)$ with first and second differences for, $x=0(0.0001)0.05(0.001)1$ and the values of $K_0(x)$ and $K_1(x)$ with first and second differences for $x=0(0.0001)0.03(0.001)1$. To simplify interpolation in the table of $Y_0(x)$ and $Y_1(x)$ in the small region between 0 and 0.0050, auxiliary functions have been tabulated at an interval of 0.0001. Similarly, auxiliary functions related to $K_0(x)$ and $K_1(x)$ have been tabulated for $x=0(0.001)0.030$.

"Applied Mathematics Series 1, Tables of the Bessel Functions $Y_0(x)$ $Y_1(x)$, $K_0(x)$, $K_1(x)$ $0 \leq x \leq 1$," may be obtained only from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., at 35 cents per copy.

AIEE Electron-Tube Conference

More than 280 people attended the AIEE conference on electron tubes for instrumentation and industrial use, which was held at the Benjamin Franklin Hotel, in Philadelphia, Pa., March 29 to 30, 1948.

The AIEE subcommittee on electronic instruments sponsored the conference, which stemmed out of a discussion about a year ago at which the need for improved electron tubes for industrial purposes was recognized. An extensive survey was made of the requirements for such improved tubes, and the conference was planned to present the result of this survey to all interested parties. This survey, the "Report on Electron-Tube Survey of Instrument Manufacturers and Laboratories," prepared by the AIEE joint subcommittee on electronic instruments, thus became the basis of the conference. Five different sessions, covering various aspects of tube-improvement problems, were held during the conference.

A dinner was held at 6:30 P.M. during which W. G. Dow (M'39–SM'43), of the University of Michigan, who is also vice-chairman of the AIEE electronics committee, acted as toastmaster.

The main speaker of the evening was W. R. G. Baker (A'19–F'28), Past-President of I.R.E. and vice-president of the General Electric Company, who is chairman of the AIEE communication and science co-ordinating committee. Dr. Baker's topic was "Manufacturing Policy With Relation to Special Tubes." This talk was the keynote for the subjects which were discussed at the third session, which immediately followed the dinner.

The after-dinner program, under the chairmanship of Professor Dow, was devoted to a discussion of design, manufacturing, and economic considerations regarding improved electron tubes for instrumentation and industrial use.

The "Report on Electron Tube Survey of Instrument Manufacturers and Laboratories," prepared by the AIEE joint subcommittee on electronic instruments, the material on which much of the information discussed at the conference was based, is available from the AIEE Order Department, 33 West 39 Street, New York 18, N. Y., at $1 to AIEE members and $2 to nonmembers.

The "Proceedings of the Conference on Electron Tubes," which will include the full text of all the talks presented as well as all the discussion that took place during the conference, is in preparation and soon will be available. It also may be ordered from the AIEE Order Department, and the price is $1.50 to AIEE members, and $3 to nonmembers.

When ordered together, the two publications may be secured for $2 to AIEE members and $4 to nonmembers.

Report of the Secretary—1947

To the Board of Directors,
The Institute of Radio Engineers

Gentlemen:

Another year of Institute progress has marched on, making it necessary for your Secretary, as provided in the Bylaws, to send you another report, covering the activities of the calendar year 1947. The customary statistics and charts are submitted with information concerning the basic factors affecting our affairs.

Four significant accomplishments must be mentioned. First, Institute growth continued at the unprecedented pace set during the years immediately preceding. This not only reflects the growing importance of the fields of radio and its allied activities, but demonstrates that our society is filling a need and has met, in considerable measure, the increased demands set by this postwar era of expansion in Communication and Electronics. A significant example of this was the unprecedented size of the 1947 Annual Convention and its exhibit activities. Second, a revised Constitution was adopted and put into effect, making it possible to activate important measures necessary for continued successful service to members and for a strengthening and broadening of our organization, scope, and fiscal condition. These include: making the Regional Representation Plan realistic through providing travel expenses to Regional Directors; continuing the Proceedings of the I.R.E. on an enlarged basis; an increase in financial assistance to Sections. Thus were solved some hitherto unsolved problems. Third, means were found to secure some extra funds, permitting the printing during 1947 of an expanded Proceedings, increasing in size month by month, absorbing a very significant portion of the backlog of technical papers resulting from the cessation of war. It was felt that this accumulation must be released with a minimum of delay to contribute promptly to the benefit of the engineer and the public. And fourth, 1947 saw the final completion of the Institute's new headquarters building, with its interior appointments and furnishings in all details, crystallization of its staff organization into a more rounded out and stable condition, better administration with all adequately housed under a single roof, and improved relations with Sections through visits of officers and staff members.

The Institute thus enters year 1948 with confidence, better fitted to meet and discharge its responsibilities than ever before.

Respectfully submitted,

Haraden Pratt, Secretary

April 15, 1948

Membership

At the end of the year 1947, the membership of the Institute, including all grades, was 21,037, a 16 per cent increase over the previous year. Before the war, the annual increase in the number of members was less than 5 per cent; in the first three years of the war, it was about 25 per cent. In 1944 and 1945, the figure dropped to 20 per cent, and to 15 per cent in 1946. The membership trend from 1912 to date is shown graphically in Fig. 2.

The distribution of members in the various grades for the years 1945, 1946, and 1947 is shown in the accompanying plot, Fig. 3. Actual figures are shown in Table I. Note that the percentage of Associates has dropped and that the percentage of Members and Senior Members has increased. The membership ratio of (Associates) to (Higher Grades) was 6 to 1 in 1944, 4 to 1 in 1945, less than 3 to 1 in 1946, and about 2 to 1 in 1947, a very satisfactory trend.

Table II shows an analysis for the past five years of the distribution of members at home and abroad. It may be noted that the foreign membership has increased rapidly since the end of the war.

It is with deep regret that this office records the death of the following members of the Institute during the year 1947:

Fellows

G. W. Kenrick (A'23–M'29–F'33)

Senior Members

Ralph R. Beal (A'15–SM'45)
W. E. Branch (M'25–SM'43)
L. Peter Graner (SM'44)
John L. Preston (M'39–SM'43)
Henry Shore (A'27–M'30–SM'43)
W. Van Nostrand (A'15–M'27–SM'43)

Members

Louis N. Persio (A'30–M'46)

Associates

Thomas M. Annis (S'43–A'43)
Frederic R. Ashley (A'46)
A. Cartier (A'45)
Jack H. Cooper (A'44)
Albert W. Glazier (A'47)
Frank C. Gow (A'44)
George L. Greves (A'20)
Hammond V. Hayes (A'21)
H. K. Huppert (A'23)
Erwin W. Kreis (A'45)
Edward M. Sorensen (A'42)
Lee Stann (A'43)
George I. Stetzel (A'46)
B. L. Weinberg (A'31)
N. A. Woodcock (A'14)

Students

Vernon J. Hentges (S'46)
R. E. Hickman (S'44)

Table I—Membership Distribution by Grades

Grade	As of Dec. 31, 1947		As of Dec. 31, 1946		As of Dec. 31, 1945	
	Number	% of Total	Number	% of Total	Number	% of Total
Fellow	239	1.1	218	1.2	210	1.2
Senior Member	2,068	9.8	1,763	9.7	1,288	8.2
Member	3,017	14.4	2,330	12.8	1,238	7.9
Associate	12,079‡	57.4	11,591†	63.9	11,145*	70.6
Student	3,634	17.3	2,252	12.4	1,898	12.1
Totals	21,037		18,154		15,779	

* Includes 2,048 Voting Associates.
† Includes 1,701 Voting Associates.
‡ Includes 1,490 Voting Associates.

Table II—Five-Year Analysis of U. S. and Foreign Membership

	1947	1946	1945	1944	1943
Total	21,037	18,154	15,779	13,137	11,079
U.S. and Possessions	18,723	15,898	14,053	11,596	9,892
Foreign (including Canada)	2,314	2,256	1,726	1,541	1,187
Per Cent Foreign	11.0	12.4	10.9	11.7	10.7

Editorial Department

In 1947 there were published in the Proceedings of the I.R.E. a total of 2576 pages (including covers). Of these, 1636 were editorial pages and 940 advertising pages. Of the editorial pages, 1183 were devoted to technical papers (including discussions and correspondence), 170 to Abstracts and References, and 283 to nontechnical material. Of the advertising pages, 822 represented paid advertising, while the remaining 118 contained useful editorial material in the form of Institute membership, Sections-meetings lists, and news of new products and of the industry in general.

The total of 2576 pages published during the year compares with 2240 in 1946 and 1912 in 1945.

The cost of printing the Proceedings during 1947 averaged $42.90 per page for an average quantity of 22,767 copies per issue. This compares with $40.45 per page for an average printing of 20,919 copies in 1946. These figures are printing costs only, and do not include salaries or overhead at Institute headquarters.

A total of 172 technical papers was published during the year. These papers were submitted by 266 authors, of whom 205 were members and 61 were nonmembers of the Institute. This contrasts with 122 papers published in 1946 by 113 member and 47 nonmember authors.

On January 2, 1947, the backlog of papers on hand in the Editorial Department, including those accepted and those under consideration, totalled 144 papers representing an estimated 1072 Proceedings pages. This figure peaked on May 29, 1947, at 171 papers totalling 1225 pages. But by December 30, 1947, the backlog had been reduced by nearly one-half to 95 papers representing 651 pages.

Stated another way, during 1947 the Institute was able to deliver into the hands of the membership the major residue of the accumulated wartime knowledge which had overloaded the publication machinery following the cessation of hostilities and the lifting of security restrictions. This was accomplished through an expanded publication program authorized by the Board of

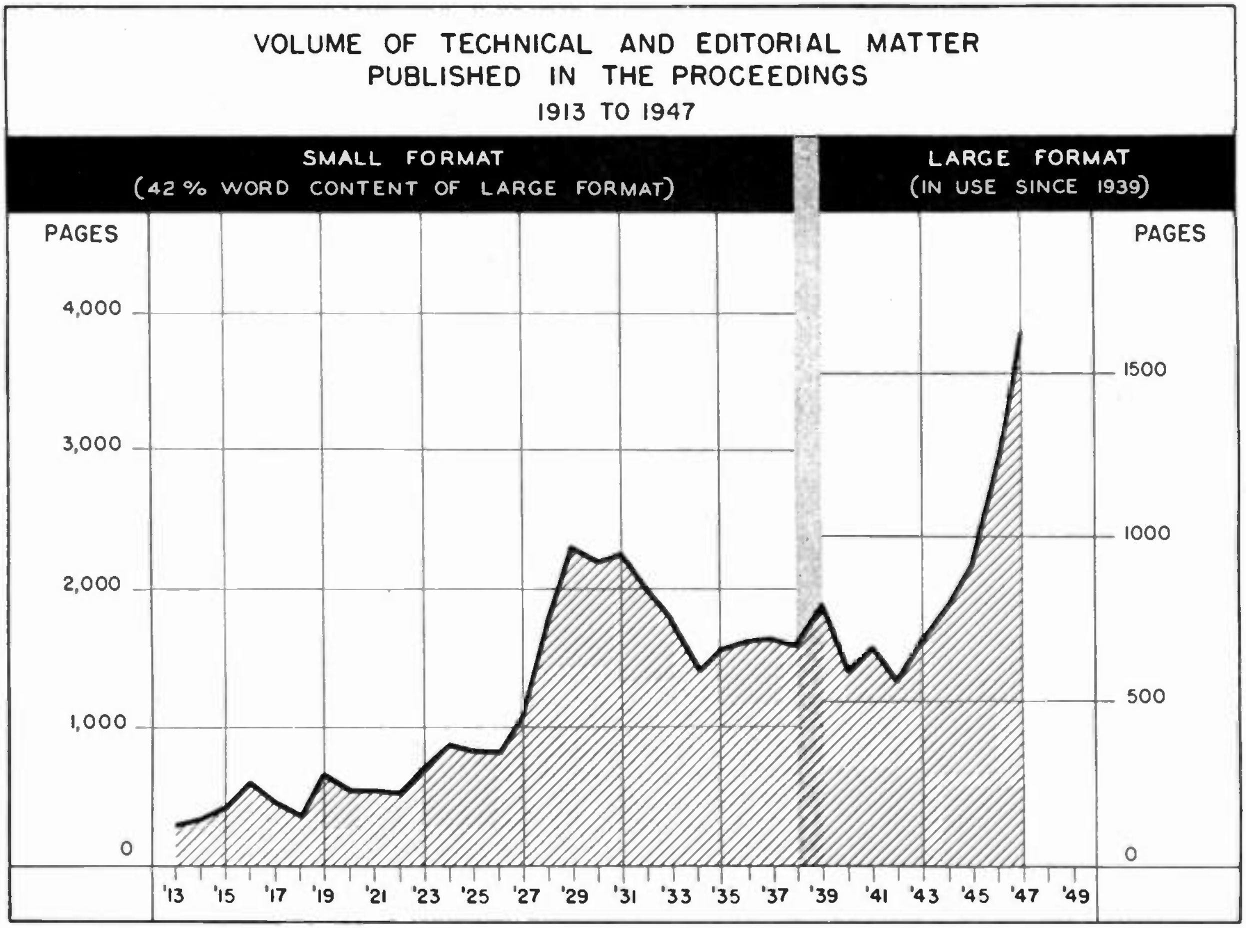

VOLUME OF TECHNICAL AND EDITORIAL MATTER
PUBLISHED IN THE PROCEEDINGS
1913 TO 1947
SMALL FORMAT
(42 % WORD CONTENT OF LARGE FORMAT)
LARGE FORMAT
(IN USE SINCE 1939)
PAGES
4,000
3,000
2,000
1,000
0
PAGES
1500
1000
500
0
'13 '15 '17 '19 '21 '23 '25 '27 '29 '31 '33 '35 '37 '39 '41 '43 '45 '47 '49

Fig. 1

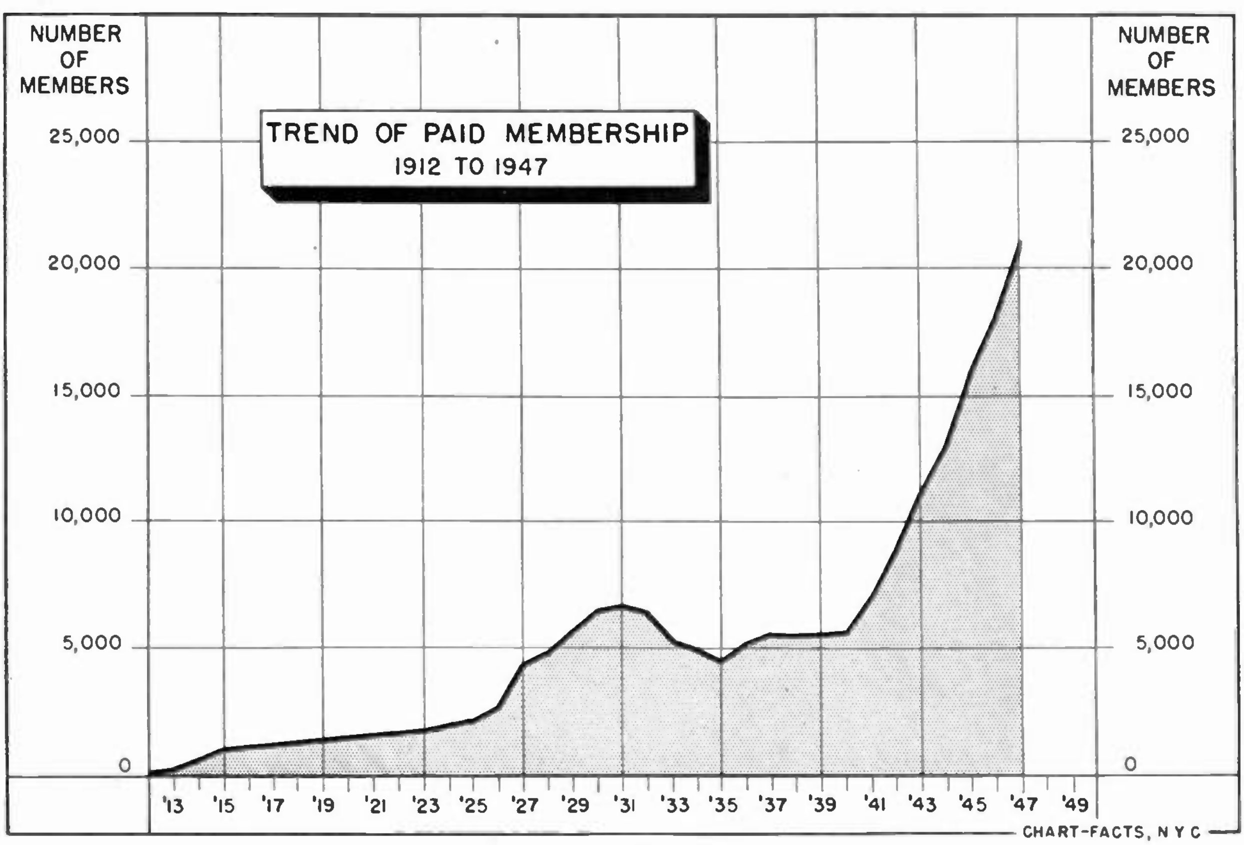

NUMBER
OF
MEMBERS
TREND OF PAID MEMBERSHIP
1912 TO 1947
25,000
20,000
15,000
10,000
5,000
0
'13 '15 '17 '19 '21 '23 '25 '27 '29 '31 '33 '35 '37 '39 '41 '43 '45 '47 '49
CHART-FACTS, N Y C

Fig. 2

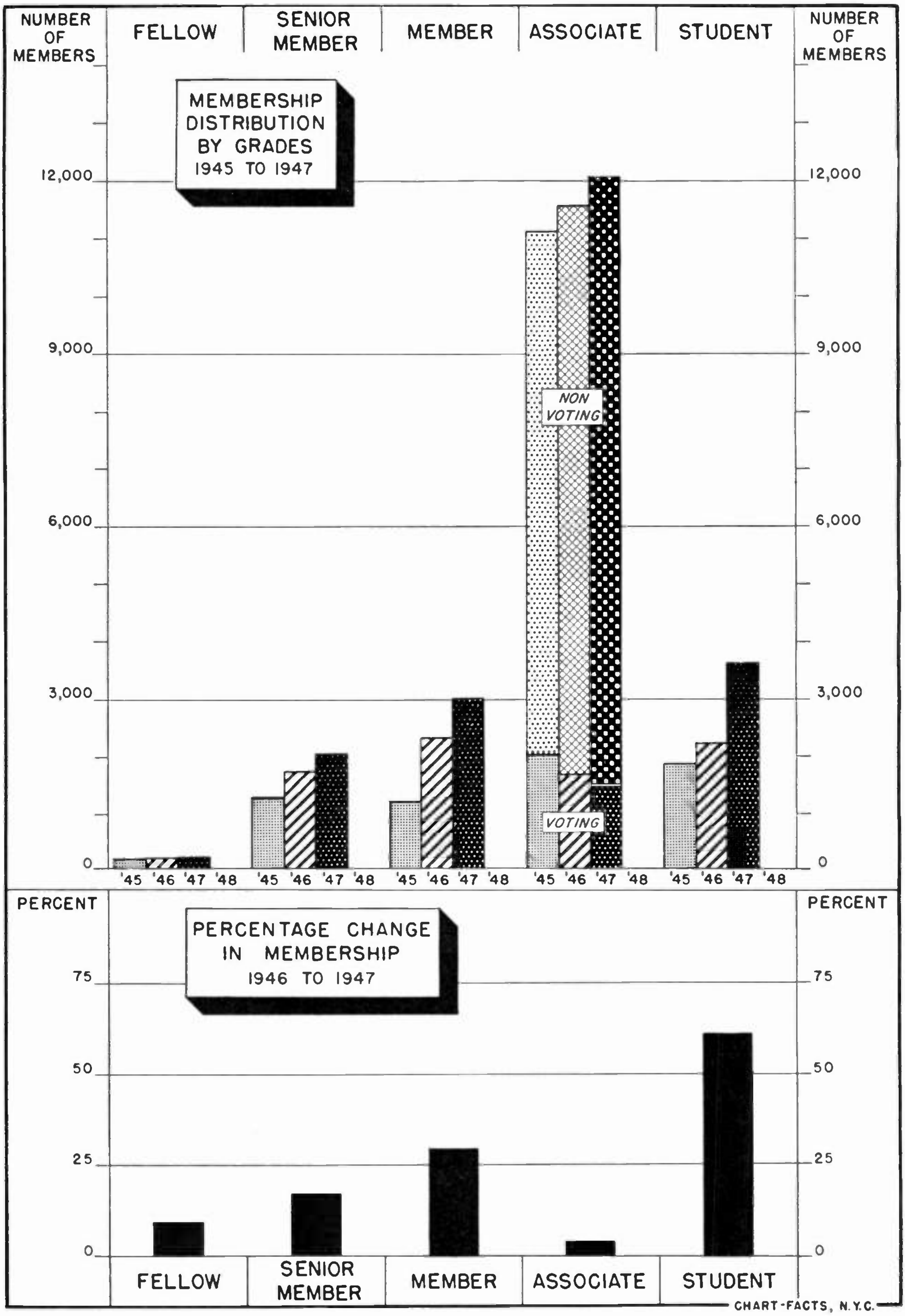
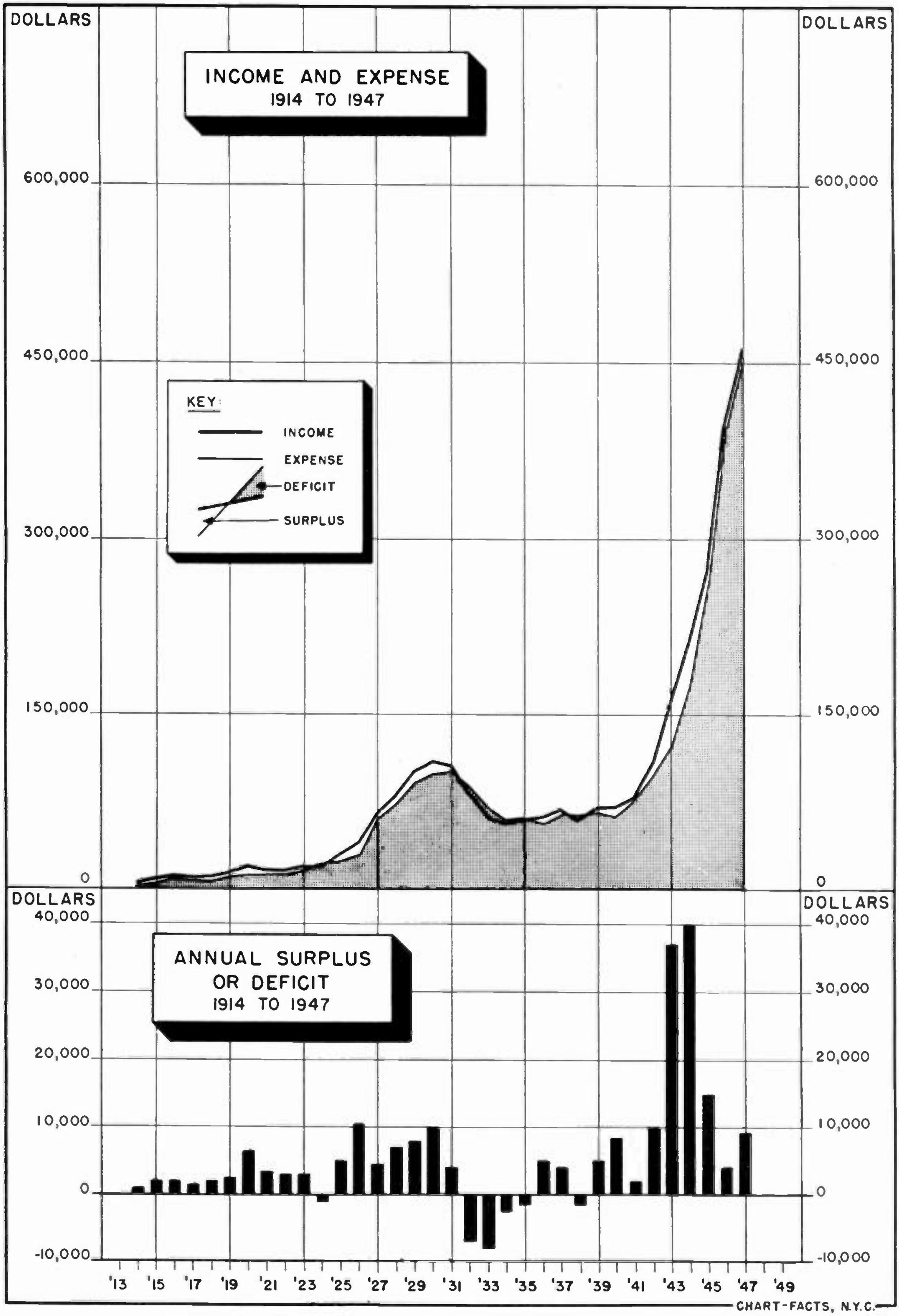

NUMBER OF MEMBERS
FELLOW
SENIOR MEMBER
MEMBER
ASSOCIATE
STUDENT
NUMBER OF MEMBERS
MEMBERSHIP DISTRIBUTION BY GRADES 1945 TO 1947
12,000
9,000
6,000
3,000
0
NON VOTING
VOTING
'45 '46 '47 '48
PERCENT
PERCENTAGE CHANGE IN MEMBERSHIP 1946 TO 1947
75
50
25
0
FELLOW
SENIOR MEMBER
MEMBER
ASSOCIATE
STUDENT
CHART-FACTS, N.Y.C.

Fig. 3



DOLLARS
INCOME AND EXPENSE
1914 TO 1947
600,000
450,000
KEY:
INCOME
EXPENSE
DEFICIT
SURPLUS
300,000
150,000
0
DOLLARS
40,000
ANNUAL SURPLUS
OR DEFICIT
1914 TO 1947
30,000
20,000
10,000
0
-10,000
'13 '15 '17 '19 '21 '23 '25 '27 '29 '31 '33 '35 '37 '39 '41 '43 '45 '47 '49
CHART-FACTS, N.Y.C.

Fig. 4

Directors in mid-1947, in anticipation of the revisions in the dues and general budget of the Institute which became effective January 1, 1948.

Toward the end of the year, under this program, there were delivered to the membership what are believed to be the largest regular journal issues (in terms of editorial content) ever published by an engineering society in the field of electrotechnology. In the issues from January through August, 1947, the average number of editorial pages was 107. Beginning with the September issue, which contained 144 pages, the expanded publication program increased this figure progressively to 176 in October and to 224 pages in the November and December issues, respectively.

It is a source of some pride that this expanded publication was achieved without increase in the size of the permanent staff. The number of Editorial Department employees was nine as of January 1, 1947, and eight on December 31, 1947, in addition to two temporary assistants engaged for 1943–1947 Cumulative Index and 1948 Yearbook work.

Publication of the Abstracts and References section was continued during the year, and remained a popular feature. Beginning with the September issue, the publication of a section devoted to "Industrial Engineering Notes" was inaugurated through the co-operation of the Radio Manufacturing Associations of the United States and of Canada.

During the year, "Standards on Television: Methods of Testing Television Receivers" were issued, and "Standards on Radio Receivers: Methods of Testing Frequency-Modulation Broadcast Receivers" were prepared for distribution in January, 1948. Copy was delivered to the printer for a five-year cumulative index, covering the period 1943–1947, for distribution in February, 1948. Work also was commenced on the 1948 I.R.E. Yearbook.

The Editorial Department is directed by Editor Alfred N. Goldsmith in matters of editorial policy, content, and format, and by Executive Secretary George W. Bailey in matters of administration, both functioning through Technical Editor Clinton B. DeSoto. It has been greatly assisted by counsel and co-operation unstintingly given by the members of the Board of Editors, Papers Review Committee, Papers Procurement Committee, and the Editorial Administrative Committee.

Fiscal

A condensed summary of income and expenses for the years 1946 and 1947 is shown in Table III, and a comparative balance sheet for these years is shown in Table IV.

TABLE III—SUMMARY OF INCOME AND EXPENSES

	1947	1946
Income		
Dues	$153,986.07	$133,715.64
Advertising, etc.	166,820.21	172,166.59
Other, such as sales of emblems, binders, convention booth space, securities, etc.	146,499.50	76,120.75
Total Income	$467,305.78	$382,002.98
Expenses		
Salaries	$129,601.08	$108,266.61
Printing Costs	92,057.48	81,084.91
Printing Year Book	169.50	14,486.55
Advertising Expenses (Promotion and Commissions)	81,471.49	61,073.29
General Administrative and Operating Expenses	56,395.53	50,438.71
Other, such as costs of emblems, binders, convention rent, administration and labor, diplomas, etc.	98,533.71	62,452.75
Total Expenses	$458,228.79	$377,802.82
Net Income	9,076.99	4,200.16

TABLE IV—COMPARATIVE BALANCE SHEET

	Dec. 31, 1947	Dec. 31, 1946
Current Assets		
Cash	$127,857.53	$133,333.62
Accounts Receivable	6,572.28	9,841.82
Inventory	12,475.66	9,227.22
Total Current Assets	$146,905.47	$152,402.66
Investments at cost	$138,796.50	$ 90,660.69
Furniture and Equipment	6,168.30	5,484.86
Prepaid Expenses	13,409.57	5,182.76
Other Assets	2,664.79	3,513.53
Total	$307,944.63	$257,244.50
Funds Assets		
Building Endowment	$594,946.81	$593,729.53
Morris Liebmann	10,687.02	11,477.79
B. J. Thompson	5,220.62	5,185.27
Total Funds Assets	610,854.45	610,392.59
Total Assets	$918,799.08	$867,637.09
Liabilities		
Accounts Payable	$ 18,521.30	$ 15,091.51
Accrued Salaries	1,316.98	701.20
Advance Payments	101,337.54	47,618.49
Income Tax Withheld	1,832.69	1,269.08
Total Liabilities	$123,008.51	$ 64,680.28
Surplus	$184,936.12	$192,564.22
Total	$307,944.63	$257,244.50
Funds		
Building Endowment	$594,946.81	$593,729.53
Morris Liebmann	10,687.02	11,477.79
B. J. Thompson	5,220.62	5,185.27
Total Funds	$610,854.45	$610,392.59
Total Liabilities and Surplus	$918,799.08	$867,637.09

The above statement was prepared from the annual report of our auditors, Messrs. Klauser and Todt, Certified Public Accountants.

Section Activities

We were glad to welcome five new Sections into the Institute during the past year. They are as follows:

Sacramento	(March)	1947
Princeton	(July)	1947
Louisville	(Aug.)	1947
Beaumont-Port Arthur	(Nov.)	1947
Des Moines-Ames	(Nov.)	1947

The total number of Sections is now 43. There has been a substantial increase in membership of these Sections, with a few exceptions where there has been a slight decrease. In addition, during the year there have been formed the following groups, unofficially designated as Sub-Sections:

Akron	(Cleveland)
Lancaster	(Philadelphia)
Long Island	(New York)
Northern New Jersey	(New York)
Toledo	(Detroit)
Urbana	(Chicago)

Student Branches

During 1947, the Institute's program with respect to Student Branches was reactivated and strengthened. The total number of Student Branches formed during 1947 was 27, twelve of which operate as joint I.R.E.-AIEE Branches. Student interest increased rapidly during the year and additional applications for the establishment of Branches are now in process. This work, under the direction of E. K. Gannett, Assistant Secretary, is very productive in building the foundations upon which future Institute progress will depend.

Following is a list of the Student Branches:

University of Alberta; University of Arkansas; California Institute of Technology; University of California; *Carnegie Institute of Technology; Case Institute of Technology; George Washington University; *University of Illinois; State University of Iowa; Kansas State College; *University of Michigan; *University of Minnesota; College of the City of New York; New York University; North Carolina State College; *Northwestern University; Pratt Institute; Purdue University; *Rutgers University; *Stanford University; University of Syracuse; University of Tennessee; *University of Texas; *University of Utah; University of Washington; *Wayne University; and *Worcester Polytechnic Institute.

Technical Activities

The I.R.E. National Convention convened from March 3 to 6, 1947, at the Hotel Commodore, New York City. Equipment displays were held on the first, second, and third floors of Grand Central Palace. A total of 11,895 persons registered and 118 technical papers were presented during the various technical program meetings. Nineteen Technical Committees of the Institute held meetings at the Hotel Commodore during this Convention. The sessions of the Standards Committee during the Convention provided an excellent occasion to introduce the 1947 Standards Co-ordinator (Mr. A of the Institute's Executive Committee) to the several Technical Committee chairmen. This meeting further provided an opportunity for newly appointed chairmen to familiarize themselves with I.R.E. procedure and to draft tentative programs for the year. Exhibition of products by a large number of manufacturers and displays by the Army, Navy, and Army Air Force at Grand Central Palace disclosed many new techniques and components which had become available due to the relaxation of wartime security. This freedom of thought and production resulted in many displays of new commercial adaptations of components produced for wartime purposes.

During the year, the Technical Committees have shown much increased activity. Several new standards on test methods are to be made available as a result of the pace set in 1947. Standards published in 1947 included those on Television Transmitters and Frequency Modulation Receivers.

A total of 73 Technical Committee meetings, including subcommittees, were held in 1947. These involved about 495 persons for a total of approximately 95,000 engineer man-hours (not including Institute staff

* Joint I.R.E.-AIEE Student Branches

people) which, on a fifty-week year, forty-hour week basis, amounts to 47.5 engineer man-years.

The new Headquarters building provided excellent facilities for committee activities and was very conducive to hard work and concentration by committee members. During the year, several joint meetings were planned and held at Headquarters, including American Standards Association-I.R.E. Technical Committees. In addition, the Institute's facilities were extended for meetings of Radio Technical Planning Board groups, a Panel of the Research and Development Board, and an annual meeting of the Board of Directors of the Radio Manufacturers Association. Three new important Technical Committees, i.e., the Nuclear Studies Committee (which will sponsor a Nuclear Symposium at the 1948 National Convention), the Audio and Video Techniques Committee, and the Electronic Computers Committee, were created, which indicates an increased trend in Technical Committee activities for the future.

West Coast Convention of the I.R.E.

Professor R. A. Millikan, retired director of the California Institute of Technology, renowned physicist and author, will be the speaker at the I.R.E. 1948 West Coast Convention, to be held September 30, to October 2, in the Biltmore Hotel, Los Angeles.

"Release and Utilization of Atomic Energy" is Professor Millikan's interesting and timely topic.

In addition to the many technical papers being scheduled, there are field trips being planned to Mount Wilson, and to broadcast, f.m., and television transmitters in the Los Angeles area. A luncheon will be held honoring all West Coast Fellow members of the I.R.E.

Calendar of COMING EVENTS

I.R.E. Electron-Tube Conference, Ithaca, N. Y., June 28–29, 1948

1948 West Coast Convention of the I.R.E., Los Angeles, September 30-October 2, 1948

National Electronics Conference, Chicago, November 4–6, 1948

Industrial Engineering Notes[1]

German Electrical Dictionary

A dictionary of German electrical symbols, including those pertaining to radio, television, and radar equipment, is now available at the Office of Technical Services, U. S. Department of Commerce. Printed copies of the dictionary (PB-85121) are available at $3.00 each. Orders should be accompanied by check or money order payable to the Treasurer of the United States.

Dry Cells Corrosion Development

A report of the National Bureau of Standards describes a recent investigation seeking more effective substitutes for mercury and chromate in curtailing corrosion in unused dry cells in the tropics. The Bureau's research in this matter was described in the May issue of "The Technical News Bulletin." Copies of the publication may be obtained from the Superintendent of Documents, Washington 25, D. C., at 10 cents each.

Magnetic Fluid Clutch

A new type of electromagnetic clutch having extensive applications, including the control of radar antennas, range finders, and high-speed electronic computers, has been developed by the National Bureau of Standards. The magnetic fluid clutch, described as "characterized by ease of control, high efficiency, smooth operation, long life, and simplicity of construction," was described in detail in the May issue of "The Technical News Bulletin." Copies may be obtained from the Superintendent of Documents, Washington 25, D. C., at 10 cents each.

Protective Films for Metal

Chromated protein coatings offering a convenient, inexpensive means of protecting metals (especially zinc, iron, brass, and aluminum) during outdoor storage in mildly corrosive atmospheres have been developed by the Bureau of Standards. "The protective value of such films," the Bureau says, "is somewhat better than that afforded by chemical surface treatments, and is much superior to that of corrosion-inhibited oils and waxes." A detailed description of the new process will be found in the June issue of "The Technical News Bulletin," monthly publication of the Bureau. Copies of the Bulletin may be obtained from the Superintendent of Documents, Washington 25, D. C., about June 10, at 10 cents a copy.

Synthetic Quartz Crystal Reports

German attempts at making synthetic piezoelectric crystals are described in five reports released by the Office of Technical Services. The reports are PB-34040, 25 cents, which describes a process for growing synthetic rock-salt crystals; PB-81281, 25 cents, preparation of Rochelle-salt crystals; PB-18784, 50 cents, which describes the work of German scientists; PB28322, 10 cents, crystal detectors, fluorescent screens; PB-28326, 10 cents, questioning of Dr. Schrieber, et al. The reports are available at the Office of Technical Services, Department of Commerce, Washington 25, D. C.

OTS Rectifier Report

A final report on American wartime research on point-contact rectifiers made from germanium-tin composition for use as second detectors and d.c. restorers in wide-band radar receivers is now on sale. The report (PB-85501; photostat, $7; microfilm, $2.50) describes the research in detail and includes supporting graphs, diagrams, photographs, and tables. Orders should be addressed to the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., and should be accompanied by check or money order payable to the Treasurer of the United States.

Measuring-Equipment Studies

The following reports, prepared by British sources, were announced by the Office of Technical Services, U. S. Department of Commerce, and are available at the OTS offices in Washington.

PB-32572—Industrial electronic measuring equipment; mimeographed, 75 cents, 22 pages; prepared by two members of the British Intelligence Objectives Subcommittee, describes an acoustic strain gage, timber and wheat moisture indicators, and other electronic measuring equipment. The investigators visited four German firms specializing in the construction of this type of equipment. The report describes several other electronic measuring devices, including a cable-fault locator, a field-strength measuring set for a.m. and f.m. which gives readings directly in microvolts, and an inductance meter, harmonic analyzer, and sweep oscillators and indicators. The report contains several circuit diagrams of the meters.

PB-42770—The manufacture of electrical measuring instruments in Germany (mimeographed, $2.25, 90 pages), a British report based on investigations of eleven German firms. Some of the instruments described are: wattmeters, light meters, frequency meters, insulating testers, radio testing apparatus, potentiometers, and distance transmission equipment. The report contains information and technical specifications for highly successful miniature motors (2 watts and under) which were made during the war by the Contessa Works of Zeiss Ikon Company at Stuttgart. Photographs, drawings, and charts are presented.

International Television Meeting

Following a meeting of the Comité International de Television in Paris recently, plans are under way for an international meeting on television at Zürich, Switzerland, to be held September 6 to 11, 1948. According to the Department of Commerce, a television exhibition will be held in connection with the meeting at the Federal Institute of Technology from September 3 to 15. It is understood that foreign exhibitors will be invited to participate in the meeting and exhibition.

Very Small Standard Capacitances

The National Bureau of Standards "in response to requests from manufacturers and users of electron tubes" has established standards and equipment for testing and certifying small fixed standards of capacitance ranging in value from 100 down to 0.001 $\mu\mu$fd. This work has involved the development of a series of primary reference standards and the construction of several

[1] The data on which these NOTES are based were selected, by permission, from "Industry Reports," issues of March 19 and 26, and April 2 and 12, 1948, published by the Radio Manufacturers' Association, whose helpful attitude in this matter is here gladly acknowledged.

fixed secondary standards and variable capacitors. "For values below 0.1 $\mu\mu$fd., a new type of primary standard capacitor has been designed, utilizing a principle which makes practical the construction of units having a capacitance as small as may be desired," the Bureau says.

Details of the development are to be published in the May issue of "The Technical News Bulletin," monthly publication of the Bureau of Standards. Copies of the publication may be obtained from the Superintendent of Documents, Washington 25, D. C., at 10 cents each.

Citizens Radio Gets Green Light

On March 23, at the 1948 I.R.E. National Convention, F.C.C. Chairman Wayne Coy announced that the Citizens Radio Service had been given the green light with the Commission's issuance of the first certificate of type approval for a transceiver. Since the general frequency allocation, more than three years ago, the new radio service has been portrayed by the F.C.C. as potentially expansive.

Chairman Coy said, "As soon as this first type-approval-set gets into production, the public can start enjoying this radio service. Having given type approval, the Commission will make it very simple to get a station license."

Technical-requirement rules setting forth the standards for manufacturing the transceivers have been adopted, and service rules governing the operation of the service will be promulgated in the near future. Tests conducted in the Commission's Laboratory indicate the set's compliance with the provisions of Part 19 of the Commission's rules governing this service. Several years of endeavor on the part of both industry and the Commission are behind this new development, which presages the advent of a service which will be available in the 460- to 470-Mc. band. The entire apparatus weighs approximately 2½ pounds, with batteries, and is comparable in size to a camera and carrying case.

The F.C.C. said: "Because equipment particularly adapted for this service has not been generally available to the public, those stations now in operation are authorized as Class 2 experimental stations. However, the initial approval forecasts the early availability of manufactured units suitable for this service, and the Commission has under consideration the establishment of additional rules to provide for simplified licensing for operation by individuals. The certificate for type approval was issued pursuant to the Citizens Radio Service rules, effective December 1, 1947, which provide for such a procedure in order to permit the manufacture of suitable equipment prior to the promulgation of additional provisions establishing regular licensing. Provisions governing private short-distance communication, radio signaling, and control of objects by radio are in preparation."

New Amateur Frequencies

The F.C.C. proposes to amend its rules governing the Amateur Radio Service to permit "hams" to use the frequency band 220 to 225 Mc. under conditions to prevent interference to present British and Canadian temporary operations with radar distance-measuring equipment in the 220- to 231-Mc. band. The new band would be in addition to those already authorized for amateur use. Copies of the proposed rule (Mimeograph No. 17899) may be obtained from the Secretary of the Federal Communications Commission, Washington 25, D. C.

Ship Radio Call Signs Reassigned

The F.C.C. proposes to reassign call signs to radio stations aboard ships and to amend its rules and regulations to specify the calls which will be assigned to certain existing ship radio and radar stations and to new stations of the same type.

An alphabetical list of the changes involved, including old and new calls, and the dates involved, will be available generally about July 1, the F.C.C. said, through sale by Cooper Trent, 1130 19th Street, N. W., Washington 6, D. C.

Radio Telephone Answering Service

Toward the end of March the F.C.C. received an application for a Class I experimental construction permit from Telenserphone Inc., of New York, to conduct radio experiments in connection with a telephone answering service for doctors. The concern proposes to use frequencies between 71,800 to 76,000 kc.

Circus to Use Mobile Radio

Ringling Brothers and Barnum & Bailey Shows, Inc., was granted a construction permit by the F.C.C. for fifteen portable and mobile radio units in the Experimental (General Mobile) Service to be used in directing the loading, unloading, and transporting of equipment in connection with exhibitions throughout the country. Radio transmitters-receivers will be installed on the circus railroad cars, automobiles, and "wagons" for nonpublic and nonentertainment purposes in moving equipment between railroad sidings and show grounds.

Installation of V.H.F. Omnidirectional Ranges

The CAA, encouraged by recent improvements which have brought the omnidirectional v.h.f. radio range to a new high in accuracy and reliability, is moving ahead to complete by July 1, 1948, installation of the 396 such facilities for which funds have been appropriated.

New Battery Specifications

The U. S. Bureau of Standards has issued new specifications for dry cells and batteries. The new specifications, to be known as American Standard C18-1947, cover all types of batteries commonly used by the public. Included are specifications for radio battery packs combining low voltage for the A circuit and a higher voltage battery for the B circuit, a more complete standardization for hearing-aid batteries, and standardized socket connections for radio A, B, and C batteries. Copies of the specification (Circular 466) may be obtained from the Superintendent of Documents, Washington 25, D. C. at ten cents each.

Industrial Mobilization Plan

The National Military Establishment Munitions Board, formerly the Army and Navy Munitions Board, has released a report on the Military Aspects of Industrial Mobilization under the heading, "Allocation of Private Industrial Capacity for Procurement Planning of the Armed Services," (Operating Procedure, Annex No. 47, Draft of March 1, 1948).

The program is designed to provide the armed services with accurate information on the industrial capacity of the country and sources of supply. From a plant survey an up-to-date inventory will be secured and maintained on American industry's "capacity for production for the wartime requirements of the armed services." "In addition," the Munitions Board said, "the results of the program ultimately will eliminate competition for the output of a single plant between procurement agencies of the armed forces, thereby enhancing wartime procurement, eliminating much confusion, and providing greater efficiency and economy in procurement."

The report includes several large radio and electric manufacturers in a list of "Major Multiservice Suppliers," but under the heading, "Products, the Manufacturing Capacity of Which will not be Converted nor at this Time Allocated," the Munitions Board lists the following classifications of electronic and communications equipment producers: electronic tubes, capacitors (paper, mica, and electrolytic), resistors, inductors, converters, amplifiers, and crystal assemblies. This category, it was explained, "covers plant capacity used in producing certain end items and components having wide use in both civilian and military fields."

Copies of the report may be obtained from the National Military Establishment Munitions Board, Washington 25, D. C.

New Marine Radio Service

A v.h.f. radiotelephone maritime-mobile service to serve the operational and business needs of ships will be set up at the earliest opportunity, the F.C.C. announced early in April. In connection with the decision, the F.C.C. granted applications for certain land radiotelephone stations and a number of associated radiotelephone stations aboard tugboats.

The Commission explained that its current action was exceptional in the marine field, although experimental grants have previously been made to communication common carriers looking toward the development of regularized v.h.f. operation in the established public maritime-mobile service in direct connection with public-service landwire telephone systems.

Military Needs May Affect Radio Procurement

It is expected that the requests for electronic and radio procurement funds of the armed services will necessarily be increased for the coming fiscal year in the light of the new program. Secretary of National Defense James V. Forrestal presented to Congress a proposal to increase the country's military budget by three billion dollars above the eleven-billion-dollar fund requested, which is now before the legislature. Secretary Forrestal estimated that one-fourth of the extra appropriation for 1949 would be expended on air power, one-fourth on personnel, and the remaining one-half on "procurement, support, maintenance and operations of the three services."

Under the national-defense budget previously submitted to Congress, the Signal Corps requested approximately thirty-eight million dollars for electronic equipment and supplies and the Bureau of Ships' Electronic Division sought about forty-seven million dollars for electronics "maintenance and procurement." These services, together with the Air Force, would be expected to increase their purchases of electronic equipment under the new procurement plan submitted by Secretary Forrestal.

Army Develops New Radio Vehicle

A new 2½-ton radio and voice communication truck, from which telephone and typed messages may be sent simultaneously a distance of 1000 miles or more, has been developed by the U. S. Army Signal Corps. The new unit, according to the Signal Corps, eliminates delay in assembling and installing equipment, and its components are designed to withstand all climatic conditions.

New Television Relay Rates

Revised rates for television network facilities became effective May 1, 1948. This establishes on a commercial basis the Bell System's television relays. Under the proposed rates, a television relay between two cities will cost the broadcaster $35.00 a month per airline mile for eight consecutive hours each day, and $2.00 a month per mile for each additional consecutive hour. For occasional or part-time service the rate will be $1.00 per airline mile for the first hour of use, and one-quarter of that amount for each additional consecutive fifteen minutes.

21 Commercial Television Stations

F.C.C. records, early in April, show 21 commercial television stations on the air; 185 applications for permission to construct; and 86 authorized construction permits outstanding.

Armstrong Files For Television

Major Edwin H. Armstrong last week filed an application with the F.C.C. for an experimental television station at Alpine, N. J., to operate with 50 kw. on 480 to 500 Mc. The application states that Major Armstrong seeks to permit the development and perfection of a new and better television system, to assist in the development of relatively high-powered transmitting equipment for such a system, and to study its service properties and the frequencies involved.

Studio-Transmitter Equipment Available

Equipment for studio-transmitter broadcast service on the 940- to 952-Mc. band is now available, and the F.C.C. recently advised f.m. station operators which have been granted temporary authority to operate such circuits on other bands, to make immediate transfer to the authorized frequencies. The ST broadcast service is allocated pursuant to action in Docket No. 6651. The F.C.C. stated: "Equipment for this frequency band has not heretofore been readily available and for this reason a number of f.m. stations which desired to use studio-transmitter circuits have been granted special temporary authorization to operate such circuits temporarily on other frequencies where interference would not result, particularly on television channels not yet in use for television broadcasting. Likewise, the prewar ST stations, which were experimental, have been continued temporarily although the frequencies on which they operate are no longer allocated to this service.

"Several manufacturers have recently announced that they are producing equipment for the 940 to 952 Mc. band, and one installation in this band is now being completed under a construction permit granted to the permittee of an f.m. broadcast station in New Hampshire. It appears now that equipment for this band will become generally available within the next few months. At the same time the demands of other services for frequencies and the increasing number of f.m. and television stations in operation make it increasingly difficult to provide ST operation without interference on any frequencies not in conformance with the frequency-service allocation. For this reason stations holding temporary authorization for ST operation on such frequencies should plan to change operation to the band 940 to 952 Mc. at an early date, and f.m. broadcast stations contemplating initial ST operation should plan to begin such operation in this band."

471 F.M. Stations On The Air

Nine conditional grants were issued by the F.C.C. for new f.m. stations as the Commission records showed 471 f.m. stations on the air early in April. There were also 904 outstanding f.m. authorizations, 151 conditional grants for f.m. stations, and 119 applications were pending.

Following is a list of f.m. stations recently: KRLD-FM, Dallas, Texas; WATL-FM, Atlanta, Ga.; WKOK-FM, Sunbury, Pa.; KBTR, Minneapolis, Minn.; WKWK-FM, Wheeling, W. Va.; WVUN, Chattanooga, Tenn.; KOA-FM, Denver, Colo.; KFYO-FM, Lubbock, Texas; WOTW-FM, Nashua, N. H.; KNX-FM, Hollywood, Calif.; KNBC-FM, San Francisco, Calif.; KFAC-FM, Los Angeles, Calif.; WFNC-FM, Fayetteville, N. C.; WCHA-FM, Chambersburg, Pa.; WESB-FM, Bradford, Pa.; WHKY-FM, Hickory, N. C.; WLEL Elmwood Park, Ill.; KGPO, Grants Pass, Ore.; WAMS-FM, Wilmington, Del.; WSIX FM, Nashville, Tenn.; KVEC-FM, San Luis Obispo, Calif.; WTTR, New London, Conn.; WBOC-FM, Salisbury, Md.; WDHN, New Brunswick, N. J.; WVMH, Hillsdale, Mich.; KDTH-FM, Dubuque, Iowa; KCMO, Kansas City, Mo.; WAPJ, Altoona, Pa.; WLAB, Lebanon, Pa.; WARM-FM, Scranton, Pa.; WBYS-FM, Canton, Ill.; WEXL-FM, Royal Oak, Mich.; WDLB-FM, Marshfield, Wis.; WKAP-FM, Allentown, Pa.; KBEE, Modesto, Calif.; WFMI, Portsmouth, N. H.; WDXY, Spartanburg, S. C., and WRVC, Norfolk, Va.

Facsimile Commercialization Urged

The adoption of operating rules and transmission standards for facsimile broadcasting was urged by both manufacturers and broadcasters at a two-day hearing in Washington. Standards recommended by the RMA and the RTPB were made a part of the record, after being presented to the F.C.C. by W.G.H. Finch, chairman of the RMA Facsimile Committee. These standards were drawn up after extended engineering conferences of industry representatives, but adoption by RMA has been delayed until after the F.C.C. acts to commercialize facsimile broadcasting.

Witnesses discussed the several types of facsimile recorders, the comparative advantages of the Simplex, Multiplex, and the new Colorfax systems of transmission, and the advantages and disadvantages of the alternative recommended recording widths of 8.2 and 4.1 inches. One of the problems the Commission will have to solve is whether facsimile broadcasting will be permitted to remain temporarily in the f.m. upper band, 88 to 108 Mc., or will be moved into a higher band. The belief was expressed by several that, through use of the Multiplex transmission system, facsimile could remain in this band without disturbing f.m. The FM Association, however, while recommending the commercialization of facsimile, asked that it be moved out of the f.m. band.

Weather Facsimile Service

A weather facsimile service for the transmission of weather maps for the Air Force Air Weather Service has been instituted by the Air Force with the co-operation of the Signal Corps. It is the first system of its kind and will put at the disposal of Air Force ground and flight personnel factual, up-to-the-minute weather data. The machines used to transmit and receive the weather maps are identical with those used in daily newspaper offices for the transmission and receipt of telephotos and facsimile newspapers.

RTCA Traffic Control Plan Approved

A further step toward putting into effect the one-billion-dollar integrated system of air traffic control proposed by the RTCA was taken in March when the President's Air Co-ordinating Committee gave its approval to the plan. This had been previously sanctioned by the Congressional Aviation Policy Board. In accepting the report, the ACC highly commended members of the RTCA Special Committee 31, which drew up the program. The Committee's announcement pointed out that in carrying out the recommendations of the RTCA report it may be necessary to modify the program from time to time, depending upon the results of specific research and development projects and upon changing operational requirements. The committee has requested the concurrence of the Research and Development Board with the ACC's action.

Increased Business In Transmitting Equipment

Sales of broadcast transmitter equipment, including a.m., f.m., television, and studio apparatus, totalled $25,800,000 in 1947, according to a tabulation of RMA member-company reports. Domestic transmitter equipment sales amounted to $24,015,-677, and export sales totalled $1,853,104.

A.m. transmitter equipment sales for the year amounted to $5,762,782; f.m. apparatus totalled $4,471,042, and television transmitting apparatus aggregated $5,304,373. Exports of transmitter equipment amounted to $932,627; studio equipment to $872,735; antenna equipment to $15,748; and miscellaneous apparatus to $31,994. U. S. Government business alone by RMA transmitter equipment manufacturers last year amounted to $135,623,975. This included $85,782,406 in sales of shipboard transmitting equipment; $26,563,668 of airborne apparatus; and $23,277,901 of all other equipment.

Domestic sales of airborne transmitting equipment in 1947 totalled $3,971,025. Sales of ground equipment amounted to $212,356. Export sales of airborne and ground transmitting equipment amounted to $655,152. Reports of the General Communications Section, of the RMA Transmitter Division, show a total of $9,631,332 in sales during 1947 of medium and v.h.f. transmitting equipment. A breakdown of the total communications equipment sales shows $4,321,979, including $496,277 in export sales of medium-frequency transmitters, receivers, and transceivers, and $5,309,353 of v.h.f. equipment, including export sales of $777,385. Marine transmitting equipment sales in 1947 totalled $3,536,312, including export sales of $1,062,132. Domestic sales of radar equipment amounted to $1,073,780. Export and domestic sales of quartz crystals last year amounted to $1,086,439, of which $1,038,941 were domestic sales.

Broadcasters' Employment Rises

The F.C.C. released an analysis of employment by broadcasting stations and networks during 1947. The report showed that, during a sample week in October, the seven networks and 1260 stations reported a total of 34,720 full-time employees, an increase of 15 per cent over the 30,100 reported by the same networks and 924 stations in February, 1947. Aggregate scheduled compensation for full-time staff personnel increased by 17 per cent, from about $2,140,000 in February to $2,508,000 in October, the F.C.C. said.

February Excise Collection

February collection of the 10 per cent excise tax on radios and phonographs and component parts totalled $6,173,908.34, an increase of $1,300,000 over the February, 1947, collections of $4,823,700.62, according to statistics of the Bureau of Internal Revenue. Excise tax collections on radios in January, 1948, were $6,186,393.68.

Canadian Radio Sales

According to information received by the Office of International Trade, Department of Commerce, sales of radio receiving sets by Canadian producers during December, 1947, totalled 86,946 units valued at $8,838,545 at list prices. Manufacturers sold 836,419 radios of all types valued at $60,399,221, compared with 568,320 units, valued at $28,849,115, in 1946. Producers' inventories of radio sets at the end of December, 1947, totalled 108,174. Radio receivers imported during 1947 totalled 112,029, valued at $3,782,585, while exports of sets numbered 52,643, valued at $1,605,078.

Receiving tubes produced in Canada during 1947 totalled 7,975,621, valued at $3,684,990, and 3,702,593 tubes valued at $1,751,957 were imported. Tube parts valued at $511,747 were imported during 1947.

U.S.-Canadian RMA Conference

A joint I.R.E.-RMA engineering study of the future adaptability of the upper bands for television broadcasting, as suggested recently by F.C.C. Chairman Wayne Coy, and a "Town Meeting for Electronic Technicians" in New York City were among new projects authorized by the RMA Board of Directors on Thursday, April 8, at the Royal York Hotel in Toronto, Canada, during the fifth U. S.-Canadian RMA conference. The meeting was the first of a two-day business and social session during which the Canadians entertained their American guests at a dinner and reception and two luncheons. The Canadians were guests and observers at the U. S. RMA board meeting Thursday afternoon, with President Max F. Balcom presiding, and on Friday morning the Americans attending the meeting of the Canadian RMA board of directors at which President S. L. Capell presided.

The RMA board of directors approved the dissolution of the Radio Technical Planning Board panels, which formerly have acted as industry advisors to the Federal Communications Commission. The RMA Engineering Department will take over television, facsimile, and other former fields of RTPB, and on broad industry technical problems a new F.C.C. advisory group of engineers from RMA and I.R.E. will be formed. The I.R.E.-RMA advisory committees will be established as needed to study particular projects, Dr. Baker said. The first committee will be assigned the task of studying the upper frequencies from 216 to 500 Mc. for possible future television expansion.

The New York "Town Meeting for Electronic Technicians" was authorized upon recommendation of Chairman J. J. Kahn of the RMA Parts Division. The metropolitan clinic for radio and television servicemen will be similar to the first "Town Meeting" held last January in Philadelphia. Chairman Kahn said that requests had been received from four other cities which want RMA "Town Meetings," but the board deferred action on these until the New York clinic is held. The other cities are Boston, Los Angeles, Chicago, and Atlanta.

RMA Meetings

The following RMA engineering meetings were held:

March 23—Subcommittee on Transmitters
March 23—Subcommittee on Capacitors
March 23—Subcommittee on Loran
March 23—Subcommittee on Magnetic Recorders
March 23—Committee on Cathode-Ray Tubes
March 24—Committee on Acoustic Devices
March 24—Committee on Thermoplastic Hookup Wire
March 24—Committee on Components Standardization
March 24 & 25—Subcommittee on System Standards of Good English Practice
March 25—Subcommittee on Depth Sounding
March 25—Subcommittee on Phonograph Records
March 25—Committee on High-Frequency Cores
March 25—Subcommittee on Electrolytic Capacitors
March 26—Subcommittee on Studio Facilities
March 26—Subcommittee on Gas-Filled Microwave Transmission Lines
March 26—Subcommittee on Crystals
March 30—Subcommittee on Flame-Hazard Investigation
April 2—Subcommittee on Flame-Hazard Investigation
April 2—Subcommittee on Studio-Transmitter Links
April 6—Committee on Dry-Disk Rectifiers
April 8—Committee on Sampling Procedure
April 10—Committee on Citizen Radio
April 15—Subcommittee on Standards of Good Engineering Practice.


SPEAKER'S TABLE AT THE THIRTY-SIXTH ANNIVERSARY I.R.E. BANQUET

Left to right—Alois W. Graf, chairman, Sections Committee; George W. Bailey, Executive Secretary, I.R.E., and Convention General Chairman; John C. Steinberg, president, Acoustical Society of America; Everitt Dillard, president, FM Association; William H. Huggins, recipient of the Browder J. Thompson Memorial Award; Lawrence C. F. Horle, recipient of the Medal of Honor; Alfred N. Goldsmith, Editor and Co-Founder of I.R.E.; Walter R. G. Baker, Junior, Past-President, I.R.E.; and Max Balcom, president, Radio Manufacturer's Association.

Greatest I.R.E. Convention Ever Held

The greatest I.R.E. Convention and Radio Engineering Show of record passed into the annals of history on March 25, concluding a four-day gathering that surpassed all expectations. A registration exceeding 15,000, larger by nearly 25 per cent than any previous attendance, attested the magnitude and success of the event.

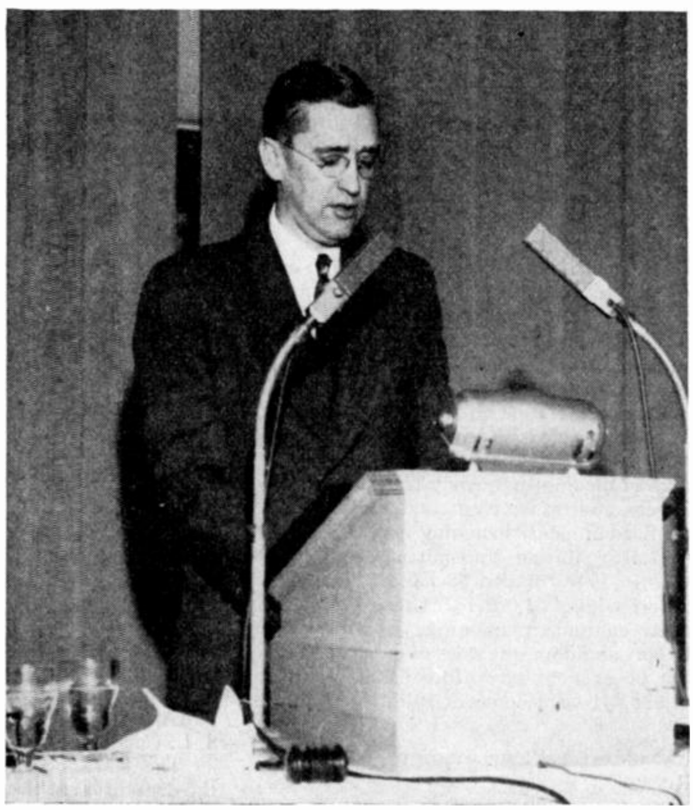
A total of 140 technical papers were presented in 27 sessions and two special symposia. The program was essentially as announced in the March issue of the PROCEEDINGS, with the addition of a special added session on synthetic crystals. Some of the papers presented are currently being published in the PROCEEDINGS, and indications are that practically all of the significant papers ultimately will find their way into these pages.

Particularly notable among the features of the Convention were the symposium on "Nuclear Science," which was attended by some 1500 and included as a special attraction a British film on the development of atomic energy, and the forward-looking symposium on "Advances Significant to Electronics," which appears destined to become known in future years as one of the more important I.R.E. sessions ever to be held.

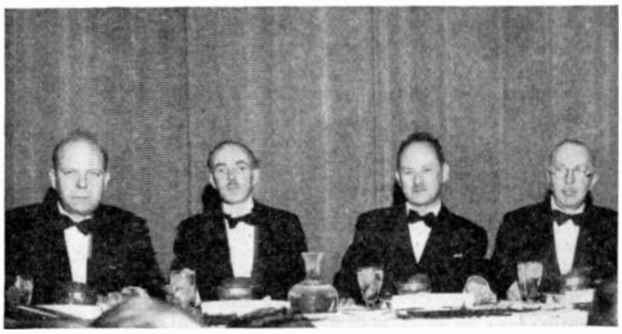
The Radio Engineering Show considerably transcended any previously held, its 190 exhibitors overflowing onto a substantial portion of the third floor of vast Grand Central Palace. Over $6,000,000 worth of radio engineering gear, from 10-kw. transmitters to microscopic components, was on display, according to Exhibits Manager W. C. Copp. Notable among the exhibits were those of the Army, Navy, and Air Force.

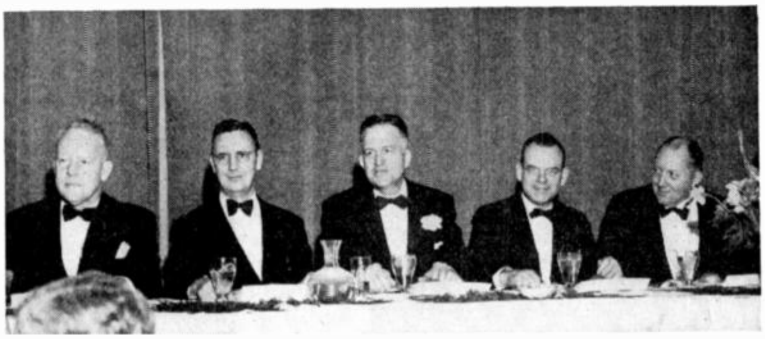
The featured speaker at the President's Luncheon was Wayne Coy, recently ap-

W. R. G. Baker, 1947 I.R.E. President, presents the gavel of office to his 1948 successor, B. E. Shackelford, at the President's Luncheon.



Wayne Coy, Chairman of F.C.C., speaking on "Fundamental Problems of Radio Engineers and the F.C.C." at the Luncheon.





SPEAKER'S TABLE AT THE ANNUAL BANQUET (CONTINUED)

Left to right—William L. Everitt, Past-President, I.R.E.; Willis Jackson, Imperial College of Science and Technology; Benjamin E. Shackelford, President, I.R.E.; John V. L. Hogan, Past-President and Co-Founder of I.R.E.; Stuart W. Seeley, recipient of the Morris Liebmann Memorial Prize; James E. Shepherd, who responded on behalf of the newly elected Fellows; Jack R. Poppele, president, Television Broadcasters Association; Stuart L. Bailey, Treasurer, I.R.E.; and Ivan S. Coggeshall, Vice-Chairman of the Convention General Committee.

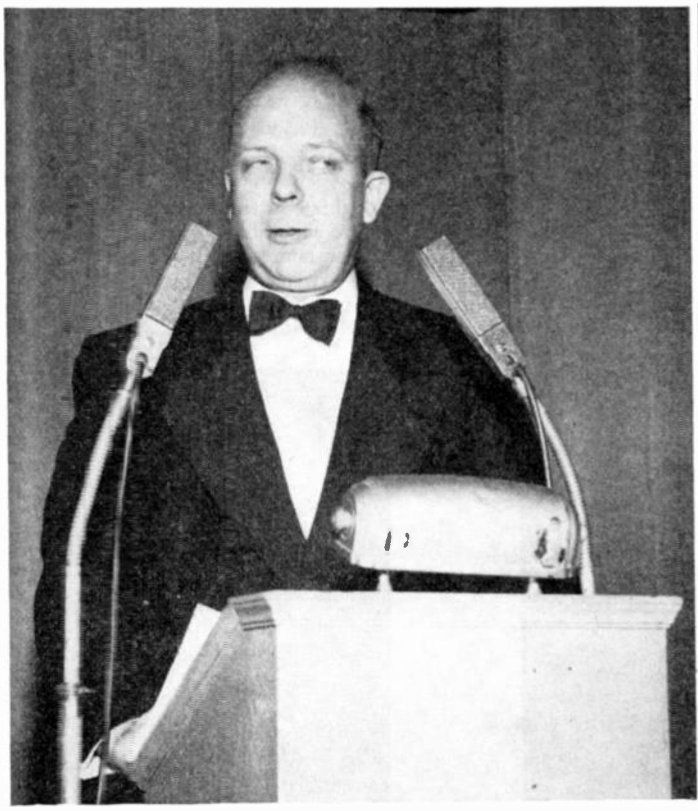
pointed Chairman of the Federal Communications Commission, making his first major address since his appointment. This address is reproduced in full elsewhere in this issue, as is the thoughtful analysis by H. B. Richmond delivered at the Annual Meeting of the Institute.

A veritable galaxy of speakers graced the Annual Banquet program. The remarks of those who spoke from prepared manuscript will be reproduced in the Waves and Electrons section of the July, 1948, issue of the PROCEEDINGS.

The Women's Program this year was run off with neatness and dispatch, and the 274 women registered at the Convention found their time well and profitably occupied. Of this number, approximately 125 attended the Tuesday-afternoon tea at I.R.E. Headquarters, a popular feature of which was an escorted tour of the building under the guidance of Editorial Department staff members.

That morning 80 ladies in two busses had journeyed out to United Nations and Lake Success, while 40 others listened to a lecture at the Frick Museum. Wednesday morning 150 ladies attended the fashion show given by Bonwit-Teller. Two popular plays occupied the same group for the afternoon. Thursday morning 35 ladies were still able to be up bright and early to leave on the bus for an all-day trip to West Point.

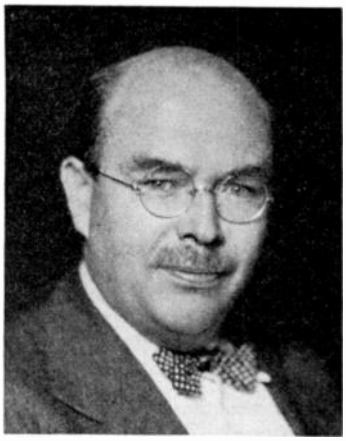
Special mention is made of the "hospitality group" of the Registration Committee, whose members were recruited after the Convention Program had gone to press, and who functioned with exceptional effectiveness under Registration Committee Chairman Frank A. Polkinghorn and Roscoe Kent, Vice-Chairman in Charge of Hospitality: Ralph W. Brown, Abner Budleman, J. R. Burns, J. T. Cimorelli, George H. Clark, F. A. Cowan, F. A. Darwin, C. E. Dean, W. H. Doherty, D. D. Donald, Beverly Dudley, Albert C. Embrechts, Carl Englund, H. C. Gawler, J. A. Hansen, John Lester, Donald McNicol, Conrad Muller, Louis Pacent, L. A. Pulley, W. Radcliff, Donald Richman, J. W. Scharge, J. E. Shaw, E. J. Simon, William Smith, A. M. Stevens, Walter P. Swain, Jr., W. J. Walsh, G. S. Wickizer, W. R. Widenor, W. H. Wilson, and F. B. Woodworth.



Dr. W. L. Everitt approaching the point of one of the stories told inimitably by him as toastmaster at the Annual Banquet.

Dr. B. E. Shackelford, President of the Institute for 1948, addressing the Thirty-Sixth Anniversary Banquet climaxing the Convention.

I.R.E. Awards



Medal of Honor—1948

L. C. F. Horle

"For his contributions to the radio industry in standardization work, both in peace and war, particularly in the field of electron tubes, and for his guidance of a multiplicity of technical committees into effective action."

❖

M. W. Baldwin

"For his fundamental investigations of the quality of television pictures."

❖

L. H. Bedford

"For his development of special circuits, in particular those used for scanning purposes, in television."

Fellow Award—1948

L. H. Bedford

Morris Liebmann Memorial Prize—1948

S. W. Seeley

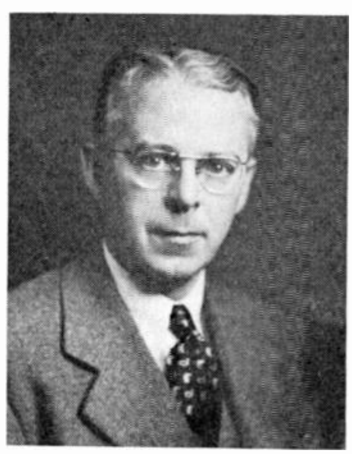
"For his development of ingenious circuits related to frequency modulation."

❖

Fellow Award—1948

M. W. Baldwin

❖



Fellow Award—1948

H. S. Black

Browder J. Thompson Memorial Award—1948

W. H. Huggins

"For his paper on 'Broadband Noncontacting Short Circuits for Coaxial Lines,' which appears in three parts in the September, October, and November, 1947, issues of the Proceedings of the I.R.E."

❖

H. S. Black

"For his work on the negative-feedback amplifier and for his application of pulse technique to radio communication systems."

❖

R. M. Bowie

"For his contributions in the fields of microwave techniques, spectroscopic methods, and standards, and for his development of means to avoid the effect of ion bombardment on cathode-ray-tube screens."

Fellow Award—1948

R. M. Bowie

Fellow Award—1948

D. E. Chambers

"For the outstanding leadership he has provided in the translation of research to engineering in one of the country's large industrial laboratories."

R. B. Dome

"For his many technical contributions to the profession and for his accomplishments in the training of young engineers."

B. S. Ellefson

"For his contributions to cathode-ray-tube development, proximity-fuze tube design, and wartime electronic research."

Fellow Award—1948

B. S. Ellefson

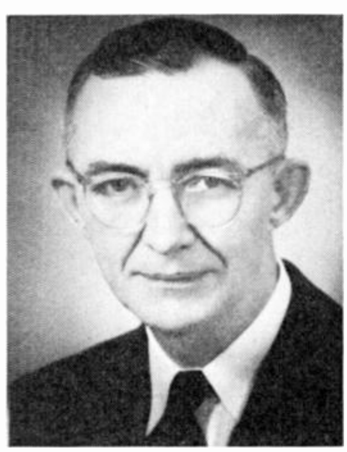
Fellow Award—1948

J. B. Coleman

"For his contributions through development, design, and technical direction of work in the field of radio transmitters."

Fellow Award—1948

R. B. Dome



Fellow Award—1948

J. J. Farrell

Fellow Award—1948

A. Earl Cullum, Jr.

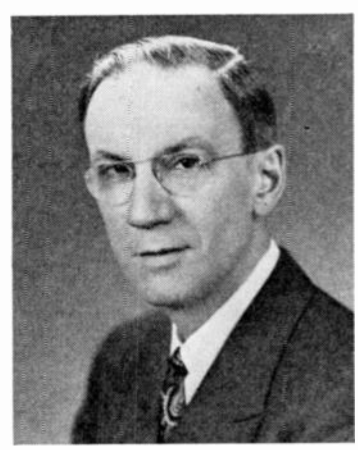
"For his contributions to the wartime radio-countermeasures program."

J. J. Farrell

"For his contributions to the design of radio and radar transmitters, and for his leadership in the establishing of industry standards."

H. C. Forbes

"For his contributions as an engineer and executive in the field of home and automobile broadcast receivers and military radio equipment."



Fellow Award—1948

H. C. Forbes

Fellow Award—1948

E. W. HEROLD

"For his contributions to theory and design in the field of vacuum tubes."

J. E. KETO

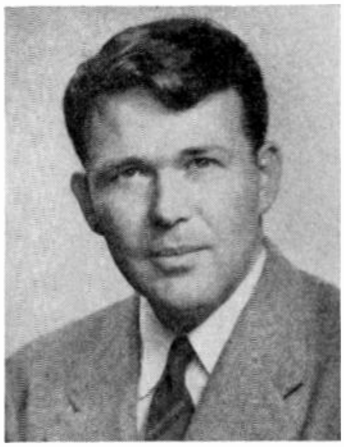
"For his contributions to the development of electronic equipment for military purposes."

N. E. LINDENBLAD

"For his many contributions to the theory and design of transmitting antennas and related equipment."

Fellow Award—1948

N. E. LINDENBLAD



Fellow Award—1948

WILLIAM R. HEWLETT

"For his initiative in the development of special radio measuring techniques."

Fellow Award—1948

J. E. KETO

Fellow Award—1948

KNOX MCILWAIN

Fellow Award—1948

J. A. HUTCHESON

"For his contributions and technical direction of work in radio research.

KNOX MCILWAIN

"For his contribution to the technical literature of radio and his activity in the field of radio aids to navigation."

D. W. R. MCKINLEY

"For his contributions to the development in Canada of radio aids to air navigation."

Fellow Award—1948

D. W. R. MCKINLEY

Fellow Award—1948

L. A. Meacham

"For his contributions in the fields of radar range measurement and pulse-code modulation."

❖

Fellow Award—1948

Albert Rose

❖

R. E. Shelby

"For his many contributions to sound and television broadcasting."

Fellow Award—1948

R. E. Shelby

Fellow Award—1948

David Packard

"For his initiative in the development of special radio testing and measuring techniques."

❖

Albert Rose

"For his contributions in the field of television camera tubes and associated equipment."

❖

Arne Schleimann-Jensen

"For his contributions as an engineer and executive in the electron-tube industry in Sweden under adverse war conditions."

❖

J. E. Shepherd

"For his contributions to the development of airborne radar armament and for his active participation and leadership in the functions of the Institute."

Fellow Award—1948

J. E. Shepherd

Fellow Award—1948

J. R. Pierce

"For his many contributions to the theory and design of vacuum tubes."

❖

Fellow Award—1948

Arne Schleimann-Jensen

❖

D. B. Smith

"For outstanding leadership in standardization activities, particularly in the field of television."

Fellow Award—1948

D. B. Smith

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Books

Ultra and Extreme-Short Wave Reception, by M. J. O. Strutt

Published (1947) by D. Van Nostrand Company, Inc., 250 Fourth Avenue, New York, N. Y. 355 pages+6½-page index+2-page bibliography+18-page references+xi pages. 248 figures. 5½×8½ inches. Price, $7.50.

Although the title of this book does not clearly define the frequency range the author intends it to cover, in the preface the range is given as 6 megacycles to 30,000 megacycles. The material included is of particular value for the lower portions of the frequency range, in which the author has had many years of experience at the Eindhoven laboratory of the Philips Company. The upper decade of the frequency range is less well covered, although some of the material which has been published since the war in U. S. and British journals has been assimilated. Just before the war, Dr. Strutt published a book in German entitled, "Modern Short-Wave Reception," and, for those readers who are familiar with the earlier work, it should be stated that the present book in English is entirely different; the chief similarity lies in the clarity of explanation with a minimum of mathematics, a technique which the author has developed through years of technical writing. Indeed, as to the present book, it has apparently been rewritten and revised up to the deadline imposed by the printer (the preface is dated April, 1947, and material from the literature up to that date is covered).

This reviewer is strongly of the opinion that separate treatment of radio reception is not only justified but essential to an advanced treatment of communication problems. This book contains enough original material to enable it to complement nicely other specialized volumes on reception which have been written since the war, some of which emphasize only the range from 3000 megacycles upward. In comparison, it is particularly gratifying to see the carefully chosen bibliography of 409 items to which reference is made at the end of each section. Thus, Dr. Strutt is evidently not one of those authors who insist on carrying the full responsibility (and credit?) for everything they include. The topics covered include propagation data, antennas, fluctuation noise, lines and waveguides, experimental techniques, and design principles. Special emphasis is given to frequency-modulation problems, so that the field is well covered. In spite of some shortcomings, to be discussed below, the book will be of value to the designer of receivers in the v.h.f. and u.h.f. ranges.

Dr. Strutt, quite correctly, has placed strong emphasis on signal-to-noise ratio problems and makes wide use of the noise figure, a concept which received world-wide recognition during the war. It is unfortunate that the discussion of this term leads to confusion rather than clarification of many points. On pp. 69–70, for example, the author sets up a straw man in the form of a so-called "first definition of noise figure," which is based on an input at an arbitrary noise temperature and which the author then knocks down by favoring a second definition based on an input at room temperature. This reviewer does not know of anyone who either proposed or used the first definition; reference to the sources cited for it show agreement with the second definition, which is the one in general use in the U. S. and Great Britain. Further confusion is caused by these two definitions when the author applies them to a cascade of two four-poles, and there appears to be no logical justification for the author's preferred equation II.2.13c. In connection with the noise figure of f.m. receivers, Dr. Strutt is also inconsistent; he states on p. 172 that the definition assumes linearity and that the noise should be measured *ahead* of the second detector (and, presumably, the limiter, if any). On p. 319, on the other hand, the noise figures of f.m. and a.m. receivers are compared on the basis of an over-all signal-to-noise ratio, i.e., one which includes the wide-band noise reduction *after* the limiter and detector of an f.m. receiver. It would be unfortunate if the latter practice were widely adopted, because it decreases the usefulness of noise figure in comparing the input circuits of receivers of different kinds. Other errors in the treatment of noise figure are found in the book, among which is equation IV.1.24b on transmission-line noise, in which a term is omitted. There is also considerable doubt that noise figures of as low as 1 to 5 can be obtained with superregeneration, as stated on page 291. The discussion of fluctuation noise in tubes and circuits is reasonably good, though one notes with surprise no reference to the early classic papers of Shottky, Johnson, and Nyquist, which are still among the best treatments. Particular praise may be given the unusually thorough treatment of feedback and its effect on signal-to-noise ratio.

The discussion of dipole-antenna bandwidth is limited to the more elementary and approximate concepts, and the failure to refer to the complete impedance data on cylindrical dipoles published in 1945 by Brown and Woodward is to be regretted. The parasitic reflector and director are also not mentioned, although they are widely used with antennas for the v.h.f. range. Topics which are treated only sketchily or not at all are local-oscillator radiation from superheterodynes, bolometer calibration methods and attenuators for signal generators, and standing-wave-ratio methods for measurement of impedance. Minor errors and omissions in the bibliography can be noted, and the author states that 100 watts c.w. can be obtained with 30,000-megacycle magnetrons; the latter result is a little optimistic for the date of writing and is not to be found in the Fisk, Hagstrom, and Hartman paper to which the author refers.

E. W. Herold
Radio Corporation of America
RCA Laboratories
Princeton, N. J.

Nomography, by Alexander S. Levens

Published (1948) by John S. Wiley and Sons, 440 Fourth Ave., New York 16, N. Y. 172 pages+ 4-page index+33-page Appendix+1-page bibliography+viii. 117 figures. 9×6 inches. Price $3.00.

This book first reviews the types of equations that are readily converted to alignment charts, and outlines the steps to be taken in developing charts of each form. The treatment is simple to understand and the methods easy to apply.The basic theory of alignment charts is lightly covered, most of the text being devoted to actual solutions of problems and chart examples. This subject and its handling is by no means new, as stated by the author.

It seems to the reviewer that this book is a modern version of the classic work from the same publisher on the subject by Lipka thirty years ago. "Nomography" is an excellent how-to-make-it book for those who simply want to makeup some charts without having to review whole sections of mathematical theories first.

A number of short cuts to the constructional rules appear in one chapter, and a large number of typical charts appear throughout the book.

Ralph R. Batcher
Caldwell-Clements
480 Lexington Ave.,
New York 17, N.Y.

High Vacua, by Swami Jnanananda

Published (1947) by D. Van Nostrand Company, Inc., 250 Fourth Avenue, New York, N. Y. 297 pages+9-page index+2-page appendix+xiii. 133 figures, 33 tables. 5½×8½ inches. Price, $5.50.

The object of this book is to present an up-to-date and thorough treatise of theory and practice in the production of high vacua. Chapter 1 deals with the derivation of the formula of the kinetic theory of gases pertinent to problems of vacuum engineering, i.e., mean free path, collision frequency, coefficients of viscosity, thermal conductivity and diffusion, and molecular streaming, etc. Vapor pressure is pressed over lightly, giving only Langmuir's original data on tungsten. Chapter 2 discusses numerous designs of mechanical, molecular, and vapor pumps. At the end of the chapter is a table of available data on nearly all of these pumps giving backing pressure, speed of exhaust, and limiting pressure. Chapter 3 discusses all types of pressure-measuring devices and again sums up the pertinent data regarding range of operation, etc. No mention is made of the "Phillips" discharge gauge which appeared in the literature in 1937. Chapter 4 deals with some of the more pertinent tools of high-vacuum apparatus giving valuable details on waxes, greases, etc., and various types of gas valves. Other subjects are treated lightly, particularly methods of detecting leaks. No mention is made of the mass spectrometer, the palladium valve, or even the simple hot-tungsten-filament detector. Chapters 5 and 6 cover very briefly the problems of occluded gases and getters, respectively.

This book contains valuable tables on the more pertinent information for high-vacua work, sums up the working formula of the kinetic theory, describes and compares a wide variety of pumps and gauges giving references to the original papers. In the reviewer's estimation it contains more information in one book on this subject than can be obtained elsewhere. It suffers somewhat by doing a more thorough job on the earlier work with little information on more recent progress. It is relatively free of errors for a first edition. One of the most annoying defects is the omission of titles from many of the figures and a failure to locate on the figures the pertinent points discussed in the text. For example, Fig. 3–16, a picture of a system for measuring vapor pressure of mercury, is utterly useless.

The book should prove valuable as a reference text, being more complete and better organized than some others.

H. D. Doolittle
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Springdale, Conn.

Theory of Servomechanisms, edited by Jubert M. James, Nathaniel B. Nichols, and Ralph S. Phillips

Published (1947) by McGraw-Hill Book Company, 330 West 42 St., New York 18, N. Y. 270 pages+5-page index+xiv. 158 figures. 9×6 inches. Price, $5.00.

The authors of this book were members of the Radiation Laboratory which operated at the Massachusetts Institute of Technology during World War II. One of the outstanding contributions of this group was the development of a system in which a sharply defined radio beam was made to remain automatically pointing at an airplane, regardless of the pilot's maneuvers (to a large extent). Previous experience had shown that an automatic system, when correctly designed, accomplishes its purpose more accurately than could a highly trained operator.

The development of such an "automatic-tracking radar" is particularly difficult because successive short radio pulses have to be reflected from the airplane; and the airplane's reflecting properties fluctuate in a completely irregular manner, due to change in its aspect resulting from yaw, roll, and pitch. A sample record of such fluctuations is shown on page 264.

A mathematical theory of just such continuous but random functions of time had been devised by N. Wiener and published in 1930 in a highly abstract paper. On the other hand, the brusque maneuvers of the pilot attempting to avoid the flak constitute a random series of discrete events, of standard statistical character. The automatic-tracking radar was thus an entirely new kind of servomechanism, since the data from which it had to work were two random time series, one continuous, the other discrete. However, mathematical methods were at hand for dealing with either type.

What the method of design was, which the Radiation Laboratory group built on these premises, is the subject of the second and most original part of the book (Chapters 6 to 8). It is a clearly and beautifully told story, which will thrill every reader cognizant with the prewar state of the art.

The first part (Chapters 1 to 4) is an excellent and thorough account of the design of servomechanisms based on sinusoidal steady-state analysis. This part will be easy and profitable reading for those already familiar with previous books by either Lauer, Lesnick, and Matson (less advanced) or MacColl (very succinct).

Chapter 5, an interlude on servo systems with pulsed data, is highly recommended to those with a mathematical sense of humor. Besides, the argument on page 231 is the simplest way to explain to a beginner the antagonism between gain and stability, a basic notion which is usually derived from elaborate stability theories.

It is remarkable how little of the contents of this book was known a relatively short time ago. At the close of World War I, even such a simple thing as the quantitative analogy of electrical and mechanical vibrations was known by very few designers, who kept their knowledge to themselves.

Now consider the level of the present work, a product of World War II. The rate of advance in the broad field of electromechanical systems is really amazing.

P. LE CORBEILLER
Harvard University
Cambridge 38, Mass.

Magnetic Control of Industrial Motors, by G. W. Heumann

Published by John Wiley and Sons, Inc., 440 Fourth Avenue, New York 16, N. Y. 589 pages+4-page index+ix pages. 365 illustrations, 6×9 inches. Price, $7.50.

For the benefit of those who are confused by terminology, magnetic control of motors (as distinguished from manual control) is by magnetic contactors, giving greater flexibility, safety, and convenience to the operator. The book contains a resume of the principles of motor operation and a description of the accessories of all types that are available for their starting-speed control and for protection. It explains the performance of motors, characteristics of control devices, and the function of fundamental control circuits. The treatment is aimed at industrial application engineers, design, operating plant, and maintenance engineers. It also covers the main electronic control equipment that is available to the industrial power field, and there is a chapter on amplidynes. In all cases the treatment is factual and covers commercially available equipment.

RALPH R. BATCHER
Caldwell-Clements
480 Lexington Ave.
New York 17, N. Y.

Frequenzmodulation, by Paul Guttinger

Published (1947) by Verlag AG. Gebr. Leemann and Company, Zürich, Switzerland. 166 pages+3-page index+14-page bibliography. 99 figures. 6×9 inches. Price, 25 Fr.

This new book, written in Switzerland, in German, is intended to be used as a text book in an advanced college course, or as a reference book by design engineers. Although, as the author states, a certain amount of mathematics is inevitable for a thorough treatment of frequency modulation, the theoretical aspects of the subject have been well balanced with useful design formulas and practical circuits, even to the inclusion of a complete circuit diagram for an 88- to 108-Mc. broadcast receiver using modern American miniature tubes.

The chapter headings are: "General Theory of Frequency and Phase Modulation"; "Distortion"; "Frequency Modulation Reception in the Presence of Noise"; "F.M. Transmitter"; "F.M. Receiver"; followed by a mathematics appendix and extensive bibliography with 295 entries. The author has made each chapter self sufficient, which greatly increases the book's utility for reference purposes. Considering the small size of the book, the subject matter has been adequately, clearly, and satisfactorily covered. Particularly noteworthy is the inclusion of a discussion on the instantaneous-frequency vs. frequency-spectrum aspects of a frequency-modulated oscillator, and a rather extensive treatment of circuit and propagation distortion. Although the author's introduction states that f.m. and p.m. are inseparably related to one another, a considerable portion of Chapter I is used in explaining the difference between the two. The same space might better have been devoted to a final chapter covering uses of f.m. to applications other than communications.

The material presented in this book can be considered modern and up-to-date (as of about January, 1947), although some of the more recent developments are considered only briefly.

L. J. GIACOLETTO
Radio Corporation of America
RCA Laboratories
Princeton, N. J.

Automatic Record Changers for the Service Man, Compiled by Howard W. Sams & Company

Published (1947) by Howard W. Sams and Company, Inc., 2924 East Washington St., Indianapolis 6, Ind. 389 pages. 374 figures. 8½×11 inches. Price, $4.95.

Any service repair man has a tough job. Radio service men have particularly tough jobs, and radio service men who encounter automatic record changers that misbehave must require a touch of clairvoyance and the luck of the Irish in order to leave a trail of satisfied customers. This manual lists some 41 different types of automatic record changers by the manufacturer's name and model number. Each changer is illustrated in several views with identifying arrows pointing out the principal parts. An "exploded" drawing of each machine illustrates the relative positioning of the multitude of parts that make up these rather complex instruments, and each part is identified by a key number, referenced to a service parts list, which gives the manufacturer's part name and part number.

The section on each make and model of changer also contains operational instructions, a description of the mechanical functioning, and, in many cases, precautionary adjustment information, service adjustments and troubles, and frequently, lubrication requirements. Many sections also contain a list of radio receivers, by make and model number, in which the particular changer has been used.

A cross index is provided, listing the trade names or manufacturers of radio receivers, with the corresponding makes and type numbers of record changers used therewith.

The authors have undertaken to provide a manual on record changers for the service man, bound in one volume, and to give him as detailed a description and source of information as possible. All principal makes of automatic changers produced in the postwar period appear to be covered, and several wire and tape magnetic and disk recorders are included as well. The introductory sections of the book are devoted to a general description of the several basic types of changers, with discussions on such things as the trip mechanism, record selecting, set-down point, and pickup cartridges. The section on drive motors is unusually complete. Although many new and revised changers will come on the market as the years roll by, the old ones will still require service, and this work will certainly fill a valuable void for the harassed service man. No provisions are announced regarding a continuity flow of information on new models, however.

Criticisms are difficult. It is felt, however, that the reactions on "wow" and "rumble" are rather incomplete and perhaps not consistent with modern understanding of those problems—but maybe the service man is not particularly interested. It is suggested, furthermore, that the service man ignore the instructions to use carbon tetrachloride on rubber-tired idlers for cleaning purposes, and use alcohol, or naphtha instead, if he wants to avoid trouble with most present-day synthetics.

No service manual can ever be a substitute for cleverness and ingeniousness, and the service man will still have plenty of trouble in finding and correcting the perverseness of most record changers; but all will, without doubt, find this volume of great helpfulness and assistance.

H. C. FORBES
Colonial Radio Corporation
1280 Main St.
Buffalo 7, N. Y.

Howard W. Sams Dial Cord Stringing Guide, Compiled by Howard W. Sams & Company

Published (1947) by Howard W. Sams, and Company, Inc., 2924 East Washington St., Indianapolis 6, Ind. 112 pages. 552 figures. 8½×5½ inches. Price, 75 cents.

One doesn't have to look in the "fine print" department in the back of this book on puzzles to find the answers. Dial stringing, without a book of rules, is a puzzle indeed, and the answers are found in some 550 diagrams, the main subject matter of the book.

Undertaking to present the diagrams of most postwar receivers, and many prewar receivers from 1938, the book presents this information in readily usable form on some 2200 different models, under 41 trade names. Since the stringing of many receivers is substantially identical, 552 diagrams suffice to cover the necessary information.

This is a first edition, intended to aid the distracted radio service man, and barring the need for bifocals to make out a few of the diagrams, it seems a comprehensive effort. All major radio manufacturer's products are covered, as well as those of many smaller and lesser-known ones.

General hints on stringing and on such subjects as causes of slipping and preferred types and sizes of cord are provided. The service man should find this volume a useful and valuable aid.

H. C. FORBES
Colonial Radio Corporation
1280 Main St.
Buffalo 7, N, Y.

I.R.E. People

J. E. Keister

J. E. Keister

J. E. Keister (A'41–SM'46) was recently appointed section engineer of the television and broadcast engineering section in the transmitter division of the General Electric Company at Electronics Park, Syracuse, N. Y.

Mr. Keister, who was born at Coburg, Iowa, and was graduated from Cornell University, has been associated with General Electric since 1935. From 1942 on he was engaged in the development of radar and television transmitting equipment at the Schenectady and Syracuse plants.

Neal McNaughten

Neal McNaughten (A'44–M'45), former chief of the allocation section in the F.C.C. engineering department's broadcast division, recently joined the staff of the National Association of Broadcasters as assistant director of the engineering department.

Born in Pueblo, Colo., in 1911, Mr. McNaughten was an amateur radio operator during his high school days. He studied at the University of Colorado, and entered the broadcast field as operator at KRGV, Weslaco, Texas, becoming chief engineer of the station in 1934. He entered government service in 1941. Between 1942 and 1945 he was first in charge of the primary F.C.C. monitoring station at Allegan, Mich., to supervise radio intelligence operations, and later conducted propagation studies for the Office of War Information in Washington, D. C. He was also affiliated with F.C.C. representation in IRAC and RTPB during the first studies of allocation problems for the Atlantic City ITC. He served as a member of the United States delegation to the meeting of American engineers looking toward the revision in Canada in 1948 of the North American Regional Broadcasting Agreement, and as a member of the United States delegation to the Atlantic City International Telecommunications Conference in 1947.

Neal McNaughten

R. H. Rudolph

Richard H. Rudolph

Richard H. Rudolph (M'46) has been appointed sales manager of precision and laboratory test equipment and crystals for the Specialty Division of General Electric Company at Electronics Park, Syracuse, N. Y. Formerly a commercial engineer in the division, he will now have charge of the sale of this equipment to nucleonic research, manufacturing, and educational organizations.

A native of Duncan Falls, Ohio, Mr. Rudolph was graduated from Ohio University with the B.S. degree in electrical engineering. In May, 1943, he joined General Electric and was assigned to the test department. For two years he worked on equipment for the armed forces at Erie, Pa., Schenectady, and Syracuse, N. Y. He transferred to an engineering section in the specialty division in October, 1945.

A. B. Fancher

A. B. Fancher

A. B. Fancher (A'43), recently-appointed section engineer of the General Electric Company at Electronics Park, Syracuse, N. Y., is a native of Hartford, Conn., and a graduate of Brown University. He has been connected with electronics engineering since 1940 and has been actively engaged in the development and design of General Electric microwave television relays and television transmitter equipment.

C. R. Miner

C. R. Miner (M'46), formerly section leader for standard-line and Musaphonic receivers with the General Electric Company, is now designing engineer with responsibility for the technical design of Musaphonic, standard-line, portable, contract, and export receivers.

C. R. Miner

K. C. Black

Donald W. Pugsley

Allan W. Parkes, Jr.

K. C. Black

K. C. Black (M'29–SM'43) has recently joined Air Associates, Inc., of Teterboro, N. J., in the capacity of chief radio engineer. Dr. Black will work under the direction of General Barney M. Giles (retired), vice-president and director of engineering, in connection with government sponsored development projects in the electronic field.

Dr. Black graduated from Harvard in 1924 and obtained his doctor's degree from this University in 1927. During a period of teaching and research at Harvard, specializing in problems associated with the application of magneto striction to the art of communication, he worked as a research physicist for the Boonton Research Corporation, gaining a number of patents on circuit and vacuum tube designs. He joined the Bell Telephone Laboratories in 1930, where he remained until shortly after the outbreak of World War II. Early in 1942 Dr. Black was appointed a member of Division 15, and later Division 13, in the National Defense Research Council.

Prior to his current post, Dr. Black was with the Aircraft Radio Corporation of Boonton, N. J.

Donald W. Pugsley

Donald W. Pugsley (A'39–M'45–SM'46), formerly section leader for television receivers in the General Electric Company's receiver division, has been named designing engineer with responsibility for the technical design of television receivers.

Mr. Pugsley, who is thirty-five years old, has been associated with the Receiver Division of the General Electric Company for thirteen years, the last ten of which were devoted to the development of television equipment and military electronic equipment.

Shortly after his present appointment Mr. Pugsley was awarded honorable mention as an "outstanding young electrical engineer" for the year 1944 by Eta Kappa Nu. While this electrical engineering fraternity makes these awards annually, the announcement of the winners chosen during the war was suspended until this year.

Donald B. Harris

Donald B. Harris (SM'45) has joined the Collins Radio Company of Cedar Rapids, Iowa, as executive assistant to the director of research, W. W. Salisbury.

Mr. Harris received the A.B. degree from Yale University in 1922, and joined the Northwestern Bell Telephone Company in St. Paul, Minn., in 1924. He was with this company in various engineering and supervisory positions until 1942, when he was called to Harvard University as technical aid to the chairman of the National Defense Research Committee, division 15: the group responsible for the development of such electronic wartime counter measures as radar jamming and "window." Mr. Harris returned to Northwestern Bell in Des Moines late in 1945 as Iowa area transmission and protection engineer, and went from that company to Collins.

Donald B. Harris

Allan W. Parkes, Jr.

Allan W. Parkes, Jr. (A'30-VA'39), was recently appointed head of field engineering and sales department at the Aircraft Radio Corporation, Boonton, N. J., with which he has been associated since 1927.

From 1917 to 1919 Mr. Parkes served with the United States Naval Aviation, and later taught physics at Lafayette College and Harvard University. He was graduated from Clark University with the class of 1922. During World War II he was awarded a Certificate of Commendation by the Navy Department for field engineering and liaison work with BuAer.

Frank Marx

Frank Marx (A'21–SM'47) has been elected vice-president in charge of advertising of the American Broadcasting Company.

Mr. Marx joined ABC in December, 1943, after twenty years' experience as a radio engineer and technical consultant. From 1930 to 1943 he was chief engineer of station WMCA, New York. He is a frequent contributor to technical publications, and, during the war, served as a consultant on several war effort and defense committees.

Daniel E. Harnett

Daniel E. Harnett (A'25–M'35–F'42) of the Harnett Electric Corporation, Port Washington, L. I., N. Y., formerly chief engineer of the Hazeltine Electronics Corporation, Little Neck, L. I., N. Y., was awarded a Certificate of Commendation by the United States Navy for his achievements during World War II. The certificate was accompanied by a citation reading, "This award is made for your outstanding supervision of a large engineering force of the Hazeltine Electronics Corporation and its subcontractors, and for your guidance in the development and coordination of production of a variety of identification and radar beacon equipments which were used interchangeably by the Allied Services."

John F. Jordan

Chairman, Cincinnati Section, 1947–1948

John F. Jordan (A'40–M'45) was born in Pittston, Pa., on November 23, 1908. He received the E.E. degree in 1932, after finishing the five-year co-operative course at the University of Cincinnati.

From 1927 through 1931, Mr. Jordan was employed in various electrical industries and in the Basic Science Research Laboratory of the University of Cincinnati as part of his training course. From 1931 to 1933 he was engaged by Professors R. S. Tour and L. R. Culver, University of Cincinnati, as an assistant in their research on gas tubes and automatic control devices. In 1933–1934 he became a partner in the Scientific Service Company, which designed and built special equipment. In 1934 he was connected with the Crosley Radio Corporation, and from 1934 to 1935 he was in charge of luminous-tube manufacture for the American Sign Company. In 1935 he joined the research staff of The Baldwin Company, Cincinnati, where he was engaged in research on electrical musical instruments, in which field he holds numerous patents. In 1941 he was placed in charge of an underwater sound project; in 1942 he became assistant chief engineer; in 1943, chief production engineer; and in 1945 he was appointed to the position of chief engineer in charge of all engineering and research for the same company.

Mr. Jordan served successively as Secretary-Treasurer and Vice-Chairman of the Cincinnati Section of the I.R.E., and he was Chairman of the Spring Technical Conference on Television, held annually in Cincinnati. He is a registered professional engineer in the State of Ohio, a member of the Engineering Society of Cincinnati, the Herman Schneider Foundation, Tau Beta Pi, and Eta Kappa Nu.

Fred W. Fischer

Chairman, Baltimore Section, 1947–1948

Fred W. Fischer (A'36–SM'46) was born in Ft. Wayne, Ind., on September 11, 1908. He is one of those individuals who has "lived" radio since the days when a Ford spark coil was something that was thought not warranting the benefit of a government license. A continuation of this early radio interest took a more commercialized form in 1932, when he was employed as an operator at radio stations WOWO and WGL in Fort Wayne, Ind.

In 1935 Mr. Fischer was appointed chief engineer of WOWO and WGL, remaining in this position until 1940, when he moved to Baltimore, Md., as design engineer at Westinghouse. His work here was chiefly directed at the design of broadcast transmitting equipment, including 5-kw. and 50-kw. a.m. and f.m. transmitters. At the outbreak of war in December, 1941, he was assigned as project engineer in charge of the design of government radar equipment.

In 1944 he turned from design engineering to application engineering in connection with government contracts, chiefly radar, and served in this capacity until the end of hostilities in August, 1945. At this time he was appointed to his present post of supervisor of sales for communications products in the Industrial Electronics Division of Westinghouse. As such, he has sales responsibility for several product lines, including marine radar, power-line carrier and, his first love, broadcast equipment. It is in the broadcast field that Mr. Fischer is best known among his many friends. From 1925 until 1940 he operated amateur radio station W9CVX. His present station is W3IWX.

Mr. Fischer has served as Secretary-Treasurer, and Vice-Chairman of the Baltimore Section of the I.R.E., and was elected its Chairman in June, 1947.

THE NEW NAVAL ORDNANCE LABORATORY

At White Oak, Maryland, near Washington, District of Columbia, the United States Navy's Bureau of Ordnance is establishing a group of thoroughly equipped laboratories wherein fundamental principles and specific applications of interest to the Navy can be comprehensively studied.

Fundamental Problems of Radio Engineers and the F.C.C.*

WAYNE COY†

I WOULD like to say first of all that in planning my talk here today I have tried to abide by your new rules for giving a technical paper.

I studied these new rules in an article in the current issue of the PROCEEDINGS OF THE I.R.E. I studied them diligently because I do have some important problems to discuss and I want to do it in the very best I.R.E. manner.

The first rule, this writer says, is to avoid "soporific monotony." Now that rule has caused me some trouble—and you will see what I mean before I am finished, I'm afraid.

Next, he says, the speaker should avoid "unfamiliar words."

I hate to quarrel with such an undoubted authority on the subject, but frankly, I don't believe that if a paper doesn't have soporific monotony or unfamiliar words, you can call it a technical paper.

It wouldn't be the real thing.

It would be counterfeit.

Among the ways to avoid this "soporific monotony," according to this author, is to open up with a startling statement, a rhetorical question, a quotation, or a humorous story.

I have made an honest effort. I have wracked my brain, but I cannot for the life of me think of any startling statement, rhetorical question, quotation, or humorous story appropriate for a gathering of radio engineers.

I know a lot of funny stories about college professors, doctors, undertakers, lawyers, and a lot more about bureaucrats—many of which I have heard from you. But I never heard one about radio engineers.

Radio engineers simply are not funny people.

They are people.

But they are not funny.

In fact, the New York *Times* had one of its observers make a study of the species recently. He published his findings the other day. He stated that radio engineers are (and I quote) "laconic and cynical, competent and steady." (And that's the end of the quote but not all of the study.)

Now I ask you, how would anyone go about startling or amusing people like that?

People who are "laconic and cynical, competent and steady"?

So I have reluctantly given up the idea of delivering a technical paper here today.

Instead, I am going to chat with you about some of the fundamental problems that you radio engineers and the Federal Communications Commission have in common.

I promise not to use any unfamiliar words.

However, I am not issuing any guarantee against "soporific monotony."

These are crowded days for all of us concerned with radio. This postwar radio boom is, in fact, so feverish that it is extremely difficult to resist the temptation to become so busy with the tasks immediately at hand that we lose sight of broad fundamental problems.

You are loaded down with various special demands requiring day-to-day action for your company or your clients. We at the Commission have a mountain of applications for broadcasting stations and many other types of applications, with the applicants—and many of their friends—understandably enough pressing for action.

And yet, when we stand back and take a good long-range view, we all realize that the fundamentals of this radio field are really our primary responsibilities.

In the first place, the American public looks to us—to you engineers and to us at the Commission—to guard and to foster the public interest, to build soundly for the future.

In the second place, you have a selfish interest here.

Your own future as members of the radio engineering profession is bound up with the way in which we decide radio's fundamental problems.

Over-all planning for radio's future should be our first order of business.

We need only to look to other fields and back on other days to see how disastrous it is to neglect this responsibility. The ruthless exploitation of our timberlands, the ruinous practices that created the dust bowl, are just two examples.

We are custodians of this public trust—the radio spectrum—not only for today, but for the next generation.

Their need for rapid communication and all the other services of this marvelous science will be even greater than ours.

If we do not want our children to accuse us of neglect or faithless stewardship when they come into their estate, we must pass on to them this heritage as efficiently managed as we have the talent to do.

We must conquer our impatience long enough to take time out to grind on the fat part of the axe.

If we fail to do this, we are going to wake up some day and find that our radio tool is too dull to do all the big jobs we have a right to expect from it.

The events of the past few days give a special urgency for the kind of radio preparedness I am talking about.

If we needed another reason for putting our radio house in order, we have it in the President's special message to Congress.

Any effort we make today toward broad-gauge planning will pay rich dividends tomorrow in accelerated progress for the radio industry as a whole and in terms of greater national security.

The spirit of mutual understanding and co-operation has always been a touchstone of progress in radio technique. Our past successes augur well for the future.

I am going to talk for a few minutes about two of the areas in which planning is of vital importance.

First, I want to report on the progress we are making in reaching world-wide and regional agreements so that all nations can get the best use out of the radio spectrum.

And second, I want to discuss the problem of making the best use of the radio spectrum above 30 megacycles.

Let's look at the international picture first.

Radio has always been an international problem, but in these days of expanded use, varied application, and more powerful beaming, planning on a global scale has become paramount.

This year, for example, there are fifteen international radio conferences.

Some of the more regular delegates are saying that the old Navy slogan ought to be changed to read: "Become a radio engineer and see the world." It has become as handy for them to know foreign languages as to know about wave propagation. These delegates are half engineer and half diplomat and their reports of their activities sound like a Fitzpatrick travelog.

The ports of call this year alone include Brussels, The Hague, Geneva, London, Stockholm, Oslo, Montreal, and (perhaps) Mexico City.

The end of the war found us with marvelous technical advances in the science of radio. It found us with enormously multiplied demands for radio in all parts of the world and for scores of new uses. But also it found us with obsolete international agreements which made it impossible for the nations of the world to obtain the maximum benefits of the technical progress of radio.

Aviation, high-frequency broadcasting, shipping, overseas radiotelephone and radiotelegraph were stymied in their efforts to employ radio on the scale that the radio engineers had made possible. In some fields, international co-operation may be merely desirable, but in the case of these radio services it is absolutely indispensable.

The first great step to modernize our

* Decimal classification: R007. Original manuscript received by the Institute, March 23, 1948. Presented, 1948 I.R.E. National Convention, New York, N. Y., March 23, 1948.
† Federal Communications Commission, Washington, D. C.

international procedures was taken at the World Telecommunications Conferences at Atlantic City last summer. Approximately 1000 delegates representing 78 nations labored there through five hot and wearisome months to lay the foundation for this new era in global radio. All of us in all phases of radio owe these men a deep debt of gratitude for their brilliant and successful efforts. Their vision, skill, zeal, and tolerance leave a high mark for all succeeding conferences to shoot at.

The Atlantic City conferees made a new table of frequency allocations to meet present-day requirements.

Then they took a new step in radio history.

Heretofore, nations have staked a claim to frequencies on a first-come, first-served basis. The method was haphazard, wasteful, and unfair. The Atlantic City conferees junked it. They agreed, instead, to allot frequencies to their stations by means of engineering principles.

That step was a triumph for the engineering profession.

In that decision, the radio engineers of the world realized a dream of years.

The lengthy series of international conferences in which we are now engaged will spell out in detail just how the broad principles of Atlantic City are to be applied in the various services.

I want to give you a brief report on the four most important conferences being held to do this work.

The first is a meeting of the Provisional Frequency Board in Geneva. The U. S. representative to the Provisional Frequency Board is Ray C. Wakefield, a former member of the Federal Communications Commission. This meeting started in January and probably will be in session for two years. Its job is to produce a draft of the first edition of the new International Frequency List as agreed upon at Atlantic City. That list will show the specific assignments of frequencies to specific stations. The Board itself will study only the problems of the fixed (point-to-point radiotelephone and radiotelegraph) service and the maritime mobile service.

Another group meeting in Geneva this spring will draft the frequency-assignment plan for the aeronautical mobile service.

Mexico City will be the scene of the next high-frequency broadcasting conference in October. It will assign the new frequencies to the domestic and international high-frequency broadcasting stations. In the United States we use these high frequencies only for international broadcasting. Our thirty-six stations now operating constitute the Voice of America. Some of the other nations use these frequencies for domestic broadcasting.

The World Aeronautical Conference at Geneva and the High-Frequency Broadcasting Conference at Mexico City will submit their recommended frequency assignments to the Provisional Frequency Board. The Board in turn will submit these two plans plus the plans for the fixed and the maritime mobile services to a special administrative conference of governments at Geneva. That Special Administrative Conference is to approve the work of the Board; that is, the first edition of the new International Frequency List. And it will set the date on which the List is to go into effect.

The target date is September 1 of next year—1949.

That date will be one of the big milestones in radio.

It will be the day the Atlantic City Radio Regulations become completely effective.

It will make the change-over from the old frequencies and the old regulations, which were adequate when they were adopted at Cairo ten years ago, but have since been outmoded by the accelerated speed of recent technical developments.

For tens of thousands of radio stations around the world, that day will be F Day—when they shift to new frequencies.

It will be a day of sweeping changes for stations employing long-distance or "high" frequencies.

Now, I don't want to start a panic among American broadcasters or American radio listeners. So I want to make it as plain as a pikestaff—clear beyond a shadow of a doubt—that these changes do not affect this nation's domestic broadcasting frequencies.

There are some bands of frequencies for which suballocation or assignment plans must be drafted on a regional basis. In the main, these frequencies lie between 1605 and 3400 kilocycles. Plans for the regional use of these frequencies by the Americas will be drafted at the Fourth Inter-American Conference. That Conference will convene next January in the rarefied atmosphere of Bogota—elevation 8000 feet.

A new permanent organization will be created at Geneva to administer the new Frequency List. It will be called the International Frequency Registration Board. As the custodian of this international public trust, the Board will keep the new Frequency List current. It will determine on the basis of engineering principles whether particular frequency assignments would cause harmful interference to services already established. The Board will be composed of eleven members. The first chairman is Captain Paul Miles, formerly chief of the Frequency Service-Allocation Division of the F.C.C. Engineering Department.

The concept of this permanent international body of experts, and the concept of a new frequency list based on engineering principles, are ideas originally proposed by radio engineers of the United States both in and out of the government.

From this you can see that we can soon bring order out of chaos in the field of international radio.

We are paving the way by this series of conferences to speed communication all around the globe, with its attendant impetus to commerce and the spread of information and understanding between peoples.

We are paving the way for the practical everyday use of such war-born marvels as radar and loran. We are moving closer to the day when we can begin to employ these marvels on a world-wide basis to enhance the safety, comfort and efficiency of people everywhere.

I have described the status of the Atlantic City radio plan in some detail to emphasize the fact that, while much has already been done, we still have much to do.

We must let nothing stand in our way.

Members of The Institute of Radio Engineers have made substantial and commendable contributions of their talents and time to this work. And I am certain that they will continue to do so.

The most significant factor affecting the second of the two main problems that we face—that is, the fullest use of the radio spectrum above about 30 megacycles—is not international co-operation, but sound planning for the future domestically. Except for certain bands of frequencies that require international standardization because of their use by ships and aircraft, this upper spectrum constitutes essentially a national problem. This is because, in general, these frequencies have short-range propagation characteristics. Those bands required for international aviation and marine purposes were standardized at Atlantic City, in accordance with our proposal to the Conference, and, therefore, need not be re-examined for some years to come.

In 1944, the F.C.C. conducted a comprehensive frequency-allocation hearing, and, in 1945, published a finding. This finding became not only the basis of the allocation proposal which the Department of State transmitted to the Atlantic City Radio Conference, but also became the blueprint for the Commission's postwar regulation of this upper spectrum. Now that we are certain that adjustments in this plan will not be required, at least for some years, for purposes of regional and world-wide standardization of aeronautical and maritime uses of radio, we must examine where we are and where we are going.

Many new uses of radio were provided for in the Commission's 1945 frequency plan.

One of these new uses, for example, was the Citizens Radio Service—a personal, short-range two-way radio service in the 460–470-megacycle band for use by the general public. The Commission has just given its type approval to the first transceiver for this new service. This means that as soon as this first type-approved set gets into production the public can start enjoying this new type of radio service. Having given type approval, the Commission will make it very simple to get a station license.

Many additional uses for radio have been suggested since 1945, so that it becomes increasingly evident that the most careful planning will have to be done on a continuous basis, if the objectives of the Communications Act and the desires of the American people are to be met.

This may suprise you, since you probably assume that planning has been done and is being done. That is perfectly true, but the point I should like to stress is that we must, from time to time, readjust our sights and make as certain as it is possible for us to do that the next generation will be able to derive the maximum benefits from the public domain we call the ether.

It is quite easy for us to color our planning on the basis of expediency and temporary problems of the present. It is equally easy for us to assume, as accomplished facts, scientific developments and advances in the art that cannot be realized.

Either of these courses of action represents an extreme. Further, the extent to which these factors may be implicit in our planning determines, in part, the soundness of a service-allocation plan.

Yet it is apparent that we must have some plan, since uncontrolled experimentation in the upper spectrum would prevent the development of essential radio services that cannot begin operations in advance of reasonably certain knowledge that their frequency allocations are secure. Moreover, it is an axiom, in problems of this kind, that no one service can be allotted an expansion of its spectrum space except at the expense of other services.

So, with a finite spectrum whose upper limit is determined at any given time by the state of the art, and with constantly expanding frequency requirements of the several services, as well as suggestions for new uses of radio, it is apparent that we have a dynamic problem for which there is no static solution.

Now the Commission has certain powers under the Communications Act, but in the final analysis the Commission is merely the sounding board of the desires of the public; therefore, the Commission must and does approach problems of this kind from the standpoint of what appears to be in the public interest, convenience, and necessity.

The first consideration in appraising the future use of this upper spectrum is an evaluation of the principal services for which spectrum space has been provided.

Broadcasting, electronic aids to navigation, vehicular communication, radio relay systems, and miscellaneous communication services—all are accorded bands of frequencies. By no means do the amounts of spectrum space, and the corresponding orders of frequency for each of these services, necessarily represent a complete satisfaction of their ultimate needs. No plan will do that. If only two services had to be accommodated, it is likely they each would wish the same bands. And we have many services and dozens of uses of radio to accommodate.

We facilitate the fullest use of the spectrum by adopting and adhering to certain technical principles, such as giving first priority to services that cannot use wire in lieu of radio and which are required for the protection of life and property. Also, we can support projects intended to result in the most economical use of the radio-frequency spectrum.

All these things we do, and more.

But anyone interested either in the future of television broadcasting or in providing mass vehicular communication service knows these measures do not, in themselves, assure the attainment of the full scope of the objectives in either of these fields.

We know the American public accepts television, and it is the duty of the Commission to provide allocations so all the people may receive this service.

I can be more explicit. A solution of the present sharing arrangements will not serve to make the available television frequencies any more adequate for a "truly nation-wide and competitive system to television" than they are now. If my predictions come true, I expect to see all television channels in the nation's 140 metropolitan areas assigned within the next twelve months.

Can we be satisfied with a metropolitan television system in the United States? I cannot conceive that anyone can answer that question in the affirmative. If we can not devise plans for "a truly nation-wide, competitive system" of television for the next generation, we are not worth our salt.

But when are we going to get at the job? How will we approach the task? Who is going to take the initiative?

Someone may say to me, "Why doesn't the Commission move ahead?" And assuming that I have been asked such a question, let me reply—at least in part.

In the first place, the Commission has pointed out the present inadequacy of channels. Secondly, it has pointed out the importance of adequate experimentation in the high band. And I now want to point out that the Commission has not had made available to it adequate information as to the characteristics of the so-called "high-band television" (475 to 890 megacycles) to enable it to write detailed standards for such a service. We at the Commission must look to the industry for more rapid developments in this area. It is an urgent matter. Soon all presently available frequencies will be assigned. Even then many people who want television service, and those who should have it will not be able to get it. Hundreds of broadcasters who want to get into the television business will not be able to do so. Are you and we going to sit heavily while this happens?

Many types of vehicles can make effective use of radio, and the Commission must satisfy this need, also.

The result is that the television broadcasting service and the land mobile service each are competing for the use of the same bands of frequencies. This is not news; it was recognized in the Commission's allocation report of 1945.

The solution to this facet of the problem, when we find it, will be news. And when I say "we," I mean just that—I include the radio industry generally, the Commission, and the general public to the full extent its best interests can be made known in a technical problem of this kind.

Besides conflicts between different services that are competing for the same frequency bands, we have fundamental technical problems that must be solved if we are to utilize the upper radio spectrum in all parts of the country.

In the prewar spectrum, geographical spacing between stations did not generally become important in the assignment of frequencies to stations. We seldom had more than a dozen stations on the same frequency. Now, we can expect to assign a given frequency in this upper spectrum in dozens, even hundreds, of places throughout the country.

Certainly we cannot expect to utilize this part of the spectrum without serious restrictions on the geographical location of stations unless we wage a relentless war on spurious emissions and unwanted harmonic radiations. The suppression requirements are particularly severe for services in which the offending transmitters are adjacent to or move among the affected receivers, such as in the amateur and urban mobile services, or are of very high power, such as in f.m. and television.

I should like to impress upon you the seriousness of this problem and ask you, as engineers, to consider as incomplete any transmitter design which fails to include adequate provision for such suppression. As to receiver design, it is evident that many present broadcast receivers in particular are deficient in regard to the suppression of oscillator radiations and in selectivity. Perhaps your efforts and ingenuity will result in simpler and more effective methods than are now available, and we may look forward to having them described in the pages of PROCEEDINGS OF THE I.R.E. in the not-too-distant future.

Ladies and gentlemen, radio is still new. Let us continue to try as hard as we can to establish a well-balanced plan for using this great natural resource, and of assuring ourselves that both the next generation, as well as our own, will be able to enjoy this heritage. It know I speak for the entire Commission when I say that we will need all the help we can get from the radio engineer.

It has been a privilege and an honor for me to address you today.

An Engineer in the Electronics Industry Prospects—Preparation—Pay*

H. B. RICHMOND†, FELLOW, I.R.E.

LAST YEAR The Institute of Radio Engineers celebrated its thirty-fifth year of existence by holding the largest-attended convention and show in its history. This event marked a milestone in its existence perhaps not fully appreciated at the time, but which has become increasingly apparent during the past year. As a closely integrated unit, the radio industry has probably passed its zenith, and instead has become a grouping of interrelated industries. If this is true, as I believe it is, then The Institute of Radio Engineers is faced with important decisions as to how it can best serve this greatly expanded industry whose bounds are now only dimly defined.

Of more immediate im portance than industry problems, however, to the young men who have recently entered our field, and to those who plan to do so in the near future, is the question of their own adequate preparation for their contemplated life work and how this can best be obtained. There have recently been some dire predictions as to the impending surplus of radio engineers, and there are many indications that such a condition may materialize. It is, however, my belief that any such surplus will result more from inadequate technical training, which limits employment to levels below the aspiration of the young engineer, than from lack of employment opportunities. Certainly, if one will accept radio in its broadest sense, whether or not the actual terminology is radio, electronics, or radionics, more positions than ever before are indicated for those with adequate preparation for them.

Let us review some of the steps in the development of our industry, their relation to other fields of science and engineering, and compare them with the experience of some of the older engineering fields. This review should provide some indication of the future for our industry.

The Institute of Radio Engineers was founded (actually, it was a combination of two other societies) by a group of men who were interested in the common problem of the transmission and reception of code signals through space. Many of the founder group had no college degree, and very few held degrees above the baccalaureate. Their early problems were largely those of empirical design and observations of transmission phenomena. This was radio of that day. A young man coming into the industry was expected to acquire soon a comprehensive grasp of the whole applied art, often including the principles, at least, of transmitting tower design. The Institute was well on toward its fifteenth birthday before an occasional paper pertaining to broadcasting appeared in its PROCEEDINGS. These early papers were largely on transmitter design. It was at this point that advanced collegiate training became more and more desirable for those entering the radio field with a desire to achieve eminence in electronic engineering. Much of the rapid advance in the radio art in the late 1920's came from the advanced workers in the telephone field, and from teachers of electrical engineering, physics, and mathematics in our universities.

When the Institute celebrated its twenty-fifth birthday in 1937, specialization and advanced degrees were clearly indicated. Ten years later, because of the violent war acceleration in the field of science, this additional preparation became a "must" for those who desired to become leaders in research. Although we must not lose sight of the fact that not all technical personnel in the radio industry are engaged in research, it is especially in the area of research that the policy relationships of The Institute of Radio Engineers to other groups, such as the American Institute of Physics, must be considered.

It has always been of interest to me that the twenty-one signers of the call to form the American Institute of Electrical Engineers in 1884 were associated with the telegraph industry, a case parallel to the formation of The Institute of Radio Engineers. For the most part, they lacked college educations. They represented, however, the keen minds in the field at that time. One of these telegraph pioneers, Norvin Green, president of the Western Union Telegraph Company, became the first president of the AIEE.

As the electrical art expanded, so did the activities of the AIEE, to the point that diversification of interest has from time to time threatened the solidarity of that society. Witness also the development of the American Society of Mechanical Engineers, with such important new fields as the automotive industry and the aeronautical industry stemming from it. Since the I.R.E. is a technical society and not a trade association, its membership coverage must be broad, but it must not seek to provide such a wide coverage through its publications and policies that it will fail to provide a solid core of communal interest to its membership.

Just what are the prospects of the electronics industry during the next decade, and what are the obligations of the I.R.E. in the expansion so clearly indicated? Are our college courses in the electronics field so organized that their graduates will be prepared for the tasks awaiting them? Before attempting to discuss these questions, I cannot refrain from expressing myself on a subject that weighs heavily on me, as I know it does on many of you.

I have vivid memories of the last three wars in which this country has participated, and I have been intimately associated with two of them. The facts facing us today are so grave that no man in the electronics industry can overlook them; and any plan he may have for the future, particularly in the field of technology, must be subject to modification, should his country need him for a larger service.

This service may not mean actual war, even though that threat must not be overlooked. It is called to our attention daily that, should we be engaged in another war, there would not be time to prepare after the first blow had been struck. You are familiar with the important part electronics played in the recent war, and with the vast emergency training of specialized electronic personnel. I firmly believe that, in the interest of national security, some way must be found to keep a substantial part of the younger engineers of our industry in intimate contact with the development and actual practice in the use of current military equipment in the electronic field. With the shameful wastage of technical personnel by the Selective Service in the last war, with lack of accord within the military as to whether universal military training or a new, quicker type of selective service would be better for the country, and with the three branches of our national defense only very recently getting together on an effective plan for unified action, I am at the moment hesitant to trust to our military the sole control over our young engineers; therefore, until a better plan is presented, I am not yet in favor of universal military training. Regretfully I must confess that something approaching it is indicated. Perhaps our own industry can do something to help solve this most unpleasant and difficult problem. The young men of our industry, in particular, should be giving this problem their intense consideration, and the I.R.E. could well make this subject one of its immediate major activities.

It is the military situation, nevertheless, that provides in the immediate future one of the large sources of employment in the electronics field. The electronics projects currently being supported by military and other public funds run into the thousands. They are being carried on within military and other governmental laboratories, as well as in collegiate and industrial laboratories. Employment statistics are purposely not generally available, but I have good reason to believe that today the man hours of degree-holding personnel expended in the military electronic field far exceed the man hours of similarly trained personnel of a decade ago

* Decimal classification: R070. Original manuscript received by the Institute, March 22, 1948. Presented, 1948 I.R.E. National Convention, March 22, 1948, New York, N. Y.

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in the entire broadcasting industry, including the manufacture of receivers, the design, construction, and operation of broadcasting transmitters, and of the tie-in networks. Subject to short-term fluctuations, I forsee no general lessening of this type of military personnel requirement over the next decade.

Broadcasting in its many forms, including television, will require an increasing number of engineers, both in the design and manufacture of receivers and in the installation and operation of equipment. Point-to-point communication, including the rapid extension of radiotelephone service, the emergency services such as police, and the many aircraft radio needs, will require substantially increased engineering personnel.

To start to enumerate the allied fields of electronics, such as heating, cooking, therapy, computers, motor control, and a host of others, together with their ancillary services, would barely scratch the surface of the possibilities through the next decade. Standing here in 1948, looking first backward a decade and then forward a decade, I shall be greatly surprised if degree-holding personnel in the very broad electronic field does not increase twentyfold in that twenty-year period.

In spite of this optimism, and assuming that there will be no immediate war, there is a very real threat of unemployment of electronic engineers in the not-too-distant future. Should this condition develop, there will probably be simultaneously a shortage of adequately trained research and development personnel. Such conflicting statements require further explanation.

A recent survey showed that one-quarter of all engineering college graduates are electrical engineers. The majority of them are in the field of communications. The war demand for communication and radar technicians interested thousands of young men in electronic techniques. The G. I. educational bill gave these young men the opportunity to convert their techniques into an engineering status. To be sure, the industry is currently operating at a level not less than twice that of a few years ago, but by the end of the next two years an increase of about fourfold in the supply of young electrical engineers with the baccalaureate degree is indicated. Taken by itself, this is not a serious employment situation. The problem comes from the fact that the concentration resulting from the desire of these young men to engage in radar and similar war developments is greater than the current indicated need.

Many of these men are in reality operations-minded in spite of their belief that they are equipped for fundamental research. Barring war, there is only a limited opportunity for these men in the operating field, either in basic communications or in such military activities as radar. There are, nevertheless, many vacancies currently existing in the military service, but such vacancies continue to prove relatively unattractive to those very persons whose military service has attracted them to the electronics field. There remains the basic urge to enter the field of research.

What is true research in this field? It is the pushing forward of frontiers in a science already far advanced in mathematics and physics, and likewise the application of this frontier knowledge to the solution of new problems. In general, the pushing forward of these frontiers or the use of this frontier science requires a training and understanding beyond that of the four-year baccalaureate degree. It is a field to be handled by those with a master's or doctor's degree, or by those who, through long experience, have attained the equivalent status. The indicated demand for such personnel is very great, particularly in view of the national defense research program in the field of guided missiles and supersonic flight. This, I believe, is why there may be a shortage of adequately trained electronic research personnel at a time when there may be a surplus of young, less adequately trained engineers.

	Bright	Dull
Busy	1. Make a line officer	3. Throw out
Lazy	2. Make a staff officer	4. Let find own place

Fig. 1—Von Moltke plan.

In no way do I deprecate the desire of young engineers to enter the research and development field of our rapidly expanding industry. I feel, however, that I would be far from honest if I did not call their attention to the currently competitive situation; niether am I unmindful that for a keen mind it is very practical to reason from the general to the specific and that intuitive judgment resulting from experience is often better than brilliance. In personnel selection, reference is often made to the Von Moltke diagram.

The German Field Marshal Von Moltke set up a simple diagram (Fig. 1) to aid in the selection of top officers in the German army. While this diagram was for a very specific purpose, it has many parallel possibilities in the field of personnel selection and as an indication of employment opportunities. Just as it shows why only one classification in four has general leadership possibilities, it similarly shows why the under-prepared man has such a difficult time to forge ahead in the currently indicated competitive situation.

Let us analyze the diagram in Fig. 2. There is no unemployment indicated for the electronics engineer in square 1. For the unaggressive person indicated in square 2 there will usually be employment, although that engineer is often inwardly dissatisfied. For number 3, Von Moltke had no use. To him, he was a dangerous man. Full of action, full of confidence, he usually was ignorant of his limitations. It was he who had the potentialities of creating a disaster. In industry he is often the leader who falls and then usually reappears in another situation. It is this man who should go on for further training to move himself to square 1. Those in square 4 are the ones who must watch the business activity curve. They are employed when business is good and unemployed when it is bad.

	Adequate Training	Insufficient Training
Active	1. Successful advance indicated	3. Dangerous because ignorant of consequences
Passive	2. Successful in routine	4. Destined to minor routine assignment

Fig. 2—Effect of training.

Now let us look at the current radio technical employment situation. In 1947, approximately 20 million radio sets for entertainment were manufactured in this country. Currently there are indications of a smaller number in 1948 because of an already filled war shortage and a probable decrease in export sales. An increase in television sets seems inevitable. The price of one television set is the equivalent of several average a.m. sets. In spite of high recorded financial embarrassments in the electronics industry in 1947 and some general hesitancy in the a.m. receiver field, because of the added impetus given by military research and the general extension of electronic principles to older industries, technical employment should continue to remain high, especially for the holders of advanced degrees. With laboratory facility costs currently running around $15,000 and annual operating costs at $10,000 for each degree-holding engineer employed, employers naturally desire to obtain adequately trained men to occupy their laboratories.

What type of education should radio engineering personnel obtain? For those truly destined for advanced research, a doctorate in physics with special emphasis on electromagnetic and probably also nuclear phenomena is indicated. As training for the doctorate is usually very flexible, little need be said here about it. The actual degree awarded is also largely a matter of local circumstance.

Except for those unable to afford the time or who want only a general training with a technical background, a master's degree is strongly recommended. The proportion of students desiring to study for the master's degree is steadily increasing, especially in those institutions in which co-operative work with industry is available. These courses usually operate on a year-round basis and provide not less than one full year of actual industrial training. A well-rounded course of this type has been very successfully conducted for about a quarter-century by the Massachusetts Institute of Technology. This industrial experience helps take the place of applied practices in which most electrical engineering courses are very deficient. I am thoroughly familiar with the academic arguments against such practical courses as applied design and machine tool or shop practice, but I, as a manufacturing employer of engineering graduates, still remain unconvinced.

In 1944 W. L. Everitt, then President of the I.R.E., rendered engineering education a real service by asking the sections to hold meetings to discuss his paper, "The Phoenix—A Challenge to Engineering Education," which was published in the September, 1944, issue of PROCEEDINGS OF THE I.R.E. These discussions, as well as the paper itself, have had an important bearing on the critical analysis that is currently being given to electrical engineering curricula.

If there is any one weakness in these curricula, I believe it to be the failure to impress on the embryo engineer the need for analyzing all problems in relation to the whole situation. Too often courses, while planned to fit into a whole program, are not actually given as such, but rather as the specialty of a particular professor.

When an engineer is hired, his employer would like to find in him not only a repository of technical knowledge together with a facility for using that knowledge, but also a spark of human enthusiasm which promises to designate him as a man among men. Engineering is a way of life, and the product of that way must be made useful to man. He must also be creative, not only in his works but also in his thoughts, and his thinking must be on a plane that leads to co-operation with his associates. Huxley expressed these principles when he wrote: "The great end of life is not knowledge—but action."

It would be most helpful if, somehow, in all courses there could run the theme of the importance of judgment. Judgment as to the quality of the data at hand, judgment as to how and when to apply that data. While many continue to insist that judgment is an innate characteristic, I believe that continued emphasis on its importance, particularly by way of illustration, will greatly improve the student in this most important characteristic.

Finally, when the student has graduated and entered on his employment, no subject is of more interest to him than pay, particularly if he has followed the current wartime vogue of early marriage. This interest is natural because it is the measure by which others appraise his ability. It is also a measure of the appraisal put on different types of talents. For example, a young engineer having a keen mathematical mind may become such a good bridge player that he can earn more as an instructor in that subject than as an engineer. He must then make a long-term appraisal as to which course he desires to follow. This example is mentioned because it is the type of decision many development engineers must make when a field engineering or administrative position is offered at rates of pay in excess of what they are currently receiving.

Competent engineers sometimes complain that technical sales positions and administrative positions pay higher salaries to persons considered by the engineer to be less competent than himself. Such a person may also have had less academic training than the complaining engineer. The law of supply and demand is inexorable in the long run and it, nearly alone, determines pay rates, barring, of course, temporary controls. If there is a shortage of chemical engineers and a surplus of electronic engineers, the chemical engineer will be the higher-paid. That situation currently exists.

In general, the young man who has decided on an engineering career is far more influenced in his choice of fields by his like or dislike of a field than by the pay opportunities in that field. There is, of course, some influence exerted where employment and pay conditions in a particular field are unusual. Tangibility is also an important factor. For example, many young men are attracted to electronic courses because they recognize electronic phenomena all around them, and in many cases they have constructed some sort of electronic equipment. On the other hand, metallurgy is a rather intangible subject to a preparatory school student, with the result that students training in this field have been rather few. Pay after graduation has accordingly averaged higher than in the electronic field.

Except as we may influence young men as to the advantages and disadvantages of the electronics field, our pay problems become quite personal because we are already in the field. Pay data is a very intangible subject because it is so difficult for any individual to make an accurate self-appraisal and thereby place himself correctly on the statistical pay curves. For anyone interested in a splendid analysis of comparative rates of pay for engineers, I recommend a study of a report published last year by the Engineers Joint Council of the 1946 Survey of the Engineering Profession. The report is entitled, "The Engineering Profession in Transition." The price is $1.00, and it may be obtained from the Council, whose headquarters are in the Engineering Societies' Building, in New York City.

I have recently made some spot checks of current pay rates for young men entering the electronics industry. They are still very confused by the effects of the war. Consideration is usually given to the value of war service, and a preferential rate of from 10 to 20 per cent is not unusual for those who have had really useful war experience in the line of work for which they are engaged. Starting pay for the holder of a baccalaureate degree in science or engineering is currently $250 a month for a standard work week. There is very little overtime now being paid for. In the case of some training courses, a rate of about $225 may be expected. Useful war experience may add up to about $50 a month, thus bringing the top starting rate up to $300 a month.

The base for a master's degree runs from $25 to $50 a month above the baccalaureate. There seemed to be more hesitancy in quoting finite figures for this degree, largely because of the war experience factor and because of the privileges under the G.I. Bill. A graduate who had useful war service, and then obtained his master's degree at the end of the war, seemed to have his experience credit and his degree credit merged in a manner hard to appraise separately. A base rate of $275 for an inexperienced holder of a master's degree, particularly if part of the training had been accelerated, can be expected. A more normal rate, including some small allowance for military experience, would be nearer $300.

The holders of the doctorate in the field of science start for about $100 a month more than do the holders of a B.S. degree. The extra time and cost is hardly worth this small starting differential. The employer is very likely to take the attitude that the holder of the B.S. degree is not expected to produce too much at the start, but is amenable to training; whereas the holder of the doctorate, while recognized for his advanced training, is nevertheless often regarded with a bit of suspicion as to his ability to turn this additional training into applied practice until he has actually proved his ability to do so.

The Engineers Joint Council study shows that doctors throughout their working life earn about $100 a month more than do the holders of a B.S. degree only. It is quite probable that a higher percentage of the holders of the B.S. degree leave the strictly research and development field for administrative work than do doctors. This study shows that the highest-paid group of engineers are those holding nontechnical management-administrative positions, with those holding technical management-administrative positions coming second. Research workers in the field of basic science come next, followed by research workers in applied science. Teaching, in which many holders of the doctorate are engaged, is twelfth on the list of nineteen classifications.

These starting rates are really interesting to only a small proportion of engineers, principally to those about to seek employment or those who have recently started, and to employers of such young engineers. What is of greater interest is the pay that men with 25 to 40 years of experience in the electronic field receive. This is so complicated by a depreciating currency that a simple answer is very difficult. For example, the starting monthly rate of $250 for today's B.S. degree men corresponds to a figure of $50 to $60 for men starting in the years immediately preceding World War I. Those men, using median reference figures, should now be receiving about $700 per month. The longer a person is away from his college training, the less significant are median figures because they contain larger divergences from the median point. Using the pre-World War I starting figures and today's actual figures, there should be an increase factor of about 12. It would, however, be entirely illogical to say that today's figure of $250 should be multiplied by 12 to obtain the median figure for 25 years hence.

There has been approximately a 3-to-1 increase in the commodity price index since just before World War I. If this be applied to the increase in pay of 12, it would represent a true factor of 4. This would mean that, if there were no change in the currency, the $250-a-month beginner of today who is right on the median point should expect a monthly rate of $1,000 in 25 to 35 years from now.

If the inflationary trends of the past, extending through centuries, continue, the actual rate should be higher than this, but the higher rate will not provide a much better standard of living. Over the last half-century a training in engineering or science has provided a modest, comfortable living for the median man. To those who have been able to use engineering as an entering step to positions of large managerial scope, the rewards have been high before the application of the near-confiscatory income tax rates of recent years. No marked change is currently indicated, but the Federal income tax, with its rapidly increasing rates for small increases in income, has been a great deterrent to the striving for larger incomes. Thus it has become a definite factor in a trend toward lower living standards, and, further, because of its adverse effect on personal savings, new equity capital is diminishing. This is just another way of stating that an artificial restriction has been placed on industrial expansion, and, in turn, new jobs.

The starting rate of $60 a month in the immediate pre-World War I era has just been discussed and compared with the current rate of $250. If a successful engineering or corporation executive then received an annual salary of $25,000, he would, prior to 1913, have paid no income tax on it. It would have all been expendable income. If he, too, received the 4-to-1 increase in salary, as has the starting engineer of today, his new gross salary of $100,000, through the Federal income tax, would currently be cut to about $40,000, assuming that he had a dependent wife but no dependent children (at least from a tax definition viewpoint). He would further be subject to state income taxes in nearly all states. Then, using the 3-to-1 commodity price change[1] referred to above, his current effective salary referred to the pre-World War I base would be about $13,000, or the equivalent of a 50 per cent cut from his original $25,000. A $13,000-a-year salary of 35 years ago would not have been considered excessive for a then-competent senior executive; yet its current equivalent of $100,000 is looked upon by many as a needless expenditure to secure competent executive talent. A little improvement may be expected through some of the proposed income tax adjustments, and possibly by a lowering of the cost of living. The income tax law also allows certain credits against gross income, such as charitable gifts, which were not considered in the above computations; nevertheless, the incentive element will remain considerably dulled.

Is there any wonder, then, that many engineers and other professional men are now less interested in making the personal and physical sacrifices required of them when they accept positions of large executive scope? Yet it is upon such men that the successful operation of our large industrial enterprises depend.

In spite of the decreasing salary incentives because of the income tax situation, there is still a genuine interest in methods of pay that provide an incentive method of remuneration for salaried personnel. There has been a steady increase in general profit-sharing, incentive bonus, wage dividend, and other general methods of reward to the engineer and executive for their contribution to profitable operations of a company. The majority of methods are general; that is, they do not single out any particular individual to try to measure his particular contribution. In large organizations there does not seem to be any effective measure that can be applied where different supervisors are rating different groups, often in widely separated cities.

The small company, however, is in quite a different situation. For about a quarter of a century, the General Radio Company has had a semiannual bonus system in which each person in the entire organization is individually rated and these ratings are coordinated by a single committee known as the Personnel Committee. In addition to the rating points, there are multiplying factors which take into account rate of pay and responsibility. After ratings have been completed, the amount allocated to the bonus is divided by the total points, and then each person receives his individual share of the total bonus, depending on his point value. There is also a profit-sharing trust where all earnings over six per cent are divided equally between the stockholders and the trust. This trust becomes a sort of emergency reserve for each individual employee, or it may serve to supplement the established pension payments.

The greatest incentive to engineers and executives, however, is what is called the *K* system, which has been in effect for over fifteen years. Under this system, each salaried employee has a base rate of pay which is competitive with that of other companies for similar positions. Regardless of whether overtime is asked of him or whether he is on short time, the base rate remains unchanged. At the start of each month, however, he is notified what *K* for the coming month will be. His base rate will be multiplied by this factor. For the calendar year 1947, *K* averaged 1.27; thus a $500-a-month man would have received an average monthly pay of $635, in addition to any profit-sharing or other general bonus payments.

K can be less than one, as well as more than one. There is published a *K* table which is made up of three factors, new orders received, shipments, and factory production at estimated billed prices. These factors have equal weights. A *K* of unity is placed at substantially the break-even point. The figures for the previous month determine the value of *K* for the following month. The *K* value is announced on the second or third working day of the month to which it applies. Our total personnel is in the 400 to 500 bracket, and 15 per cent of them are on the *K* system.

It has been felt that this incentive system has worked very well. It is often interesting to see the ingenious methods which have been taken by supervisors to boost one or more of the factors determining *K* when it has been observed that a decline in *K* is indicated. A chart of the weekly figures affecting *K* is published during the month, so that there is always a fair indication of what the next value of *K* is to be.

While persons in the higher tax brackets gain little as *K* is increased, their interest is just as keen as that of those in the lower tax brackets. Such an interest must mean that satisfaction from meeting the challenge is as great as that of the additional financial reward. It re-emphasizes the quatrain expressing the feeling of the true amateur sportsman:

Not the quarry, but the chase;
Not the laurel, but the race;
Not the hazard, but the play;
Make me, Lord, enjoy alway!

[1] On April 2, the Federal income tax law was changed to permit division of income between husband and wife. This could mean a saving of as much as one-third in the example used, thus increasing the stated net amount of $60,000 and the equivalent pre-World War I amount to $20,000.

Modern Design Features of CBS Studio Audio Facilities*

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Summary—**A significant change is taking place in the appearance of the control rooms of modern broadcasting studios. Only a few years ago this key point in the origination of a radio program was cluttered with racks and cabinets filled with audio gear. Today, the modern control room presents an air of spaciousness, as all equipment is out of sight within a small, functional, desk-size control console. In accomplishing this, no sacrifice has been made in performance, ease of operation, or accessibility. In fact, the modern control console provides many conveniences and facilities not present in the older installations. This paper discusses the considerations involved in the design of this modern type of broadcasting-studio audio control console. A number of new and novel features, not employed heretofore, are described. Many of the fundamental ideas and methods presented are applicable to services other than broadcasting.**

Introduction

A BROADCASTING STUDIO which serves as the point of origin for large and elaborate radio productions must be equipped with audio facilities of adequate scope and flexibility to permit all production requirements to be completely and conveniently handled. An audio installation capable of meeting these requirements in an efficient manner will involve a large number of audio equipment components all of which must be assembled in a manner permitting convenient accessibility both for operation and maintenance of the installation.

These audio-equipment components have often been assembled in relay racks. An illustration of such an installation, made in the years prior to the war, is shown in Fig. 1. Relay-rack installations are usually quite large in size, consuming a considerable amount of control-room floor space, and, in addition, seldom present an attractive appearance. To overcome these difficulties, some broadcasting plants have been arranged with only the operating controls and monitoring devices installed in the control room, and all other equipment, together with similar equipment from other studios of the plant, installed on racks in a centrally located equipment room. This arrangement does much to relieve the cluttered appearance of the control room. However, no saving in the actual space requirement of the installation is achieved. Furthermore, considerable expense is incurred by reason of the numerous interconnecting cable runs that are required and the relatively large amount of work that must be undertaken during the initial installation to interconnect all the component units.

While installations of large physical size may not appear undesirable at first consideration, it must be remembered that broadcasting studios are usually located in the center of the business or theater section of large cities, and the rental cost of every square foot of floor area is relatively high. Therefore, the actual cost of a large installation over a period of time may prove considerably greater than it appears initially, since the equipment occupies valuable floor area that may well be used for other purposes.

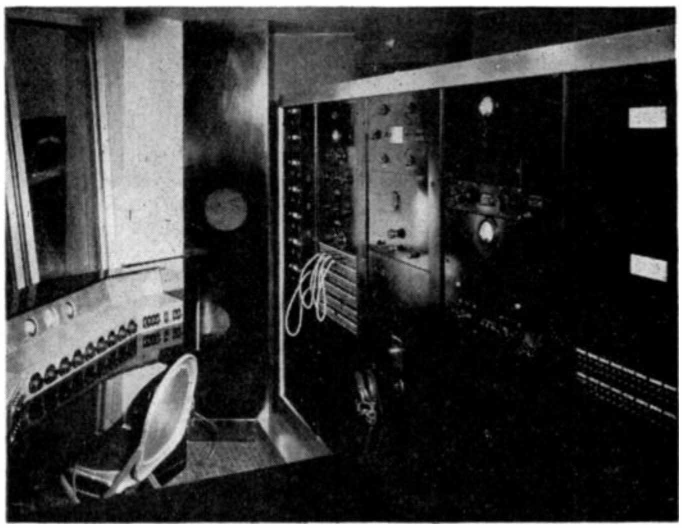


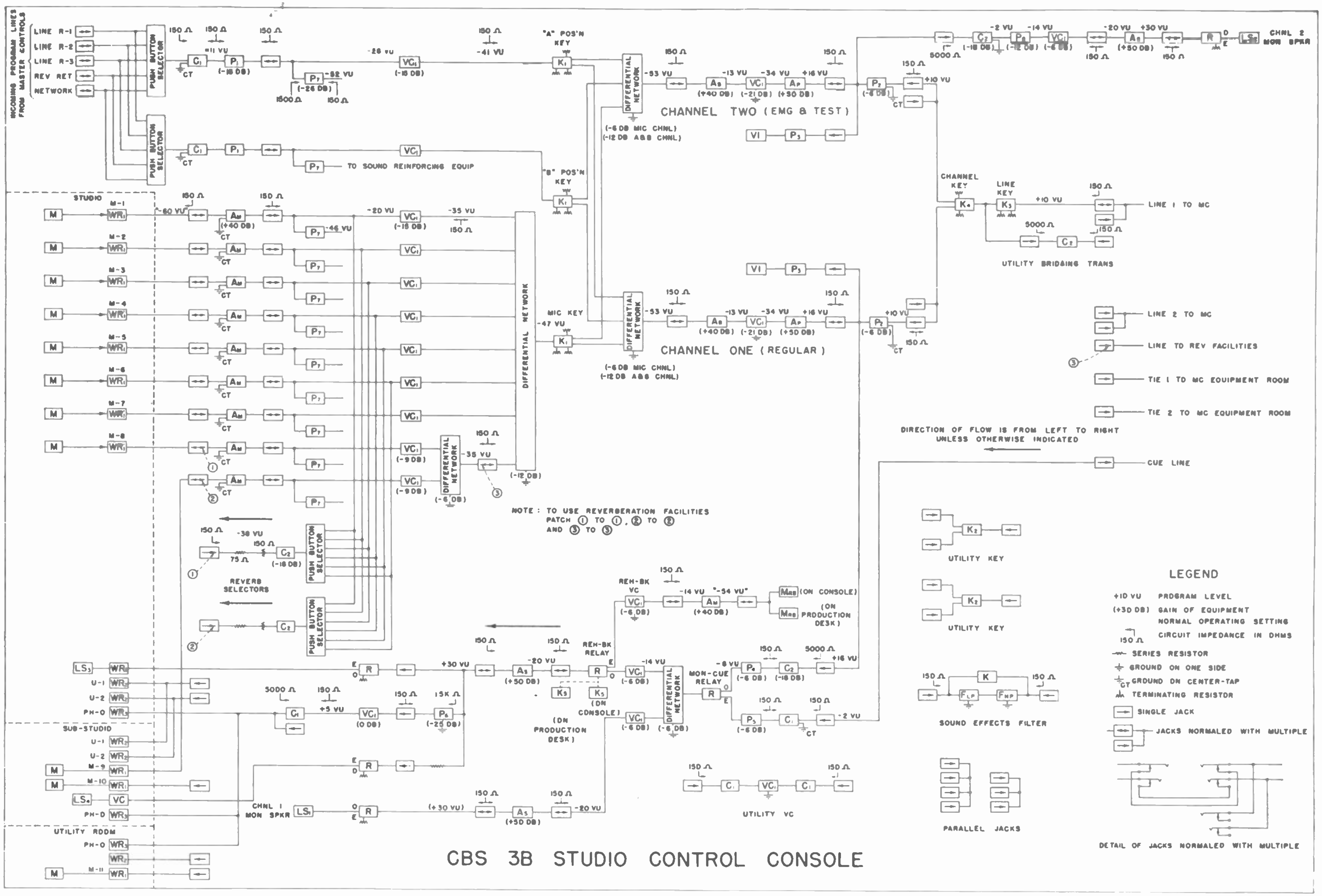
Fig. 1—A radio-theater control-room installation made about ten years ago. Five relay racks are required for the various amplifiers and other audio components, while the operating controls and visual monitoring facilities are centralized on the desk-mounted control console. A wall-mounted equipment cabinet, not shown, is also employed to mount an audio a.c. fuse panel, sign relays, d.c. relay power supply, and audio terminal blocks.

The size of these early installations was due, in large measure, to the physical dimensions of the individual equipment components then available. One of the factors that made it possible to house in a single desk-size unit considerably greater facilities than were incorporated in this large installation was the use of the small, compact amplifier units. Preliminary amplifiers, for example, occupy approximately one-eighth the space required by those shown in the above illustration.

It has been contended that the relay-rack method of equipment assembly (which invariably results in a space-consuming installation since adequate access space must be provided both in front and in back of the racks) provides an installation in which all equipment components are readily accessible for maintenance. While it is true that a well-planned rack-mounted installation is quite accessible, the small, space-saving, single-unit audio console to be described is just as accessible for maintenance. As a matter of fact, the plug-in amplifier and power-supply units are considerably easier

* Decimal classification: R613.11. Original manuscript received by the Institute, December 2, 1947; revised manuscript received, February 3, 1948. Presented, 1948 I.R.E. National Convention, March 24, 1948, New York, N. Y.

† Columbia Broadcasting System, Inc., New York, N. Y.



LEGEND

A_M	PRELIMINARY AMPLIFIER	C_2	BRIDGING TRANSFORMER	K_3	LINE KEY SWITCH	LS_3	STUDIO LOUDSPEAKER	P_2	FIXED "H" PAD 6DB 150 150 Ω	P_7	BRIDGING "T" PAD 15K 150 Ω	VI	VOLUME INDICATOR
A_B	BOOSTER AMPLIFIER	F_{LP}	ADJUSTABLE LOW PASS FILTER	K_4	CHANNEL KEY SWITCH	LS_4	SUB-STUDIO LOUDSPEAKER	P_3	VOLUME INDICATOR ATTENUATOR	P_8	FIXED "T" PAD 12DB 150 150 Ω	WR_1	MICROPHONE WALL RECEPTACLE
A_P	PROGRAM AMPLIFIER	F_{HP}	ADJUSTABLE HIGH PASS FILTER	K_5	REHEARSAL BREAK KEY SWITCH	M	MICROPHONE	P_4	FIXED "T" PAD 6DB 150 150 Ω	R	RELAY	WR_2	UTILITY WALL RECEPTACLE
A_S	MONITORING AMPLIFIER	K_1	MIXER KEY SWITCH	LS_1	CHNL-1 MONITOR LOUDSPEAKER	M_{RB}	MICROPHONE, REHEARSAL-BREAK	P_5	ADJUSTABLE "T" PAD 150 150 Ω	VC_1	VOLUME CONTROL 150 150 Ω	WR_3	PHONE-CUE WALL RECEPTACLE
C_1	LINE TRANSFORMER	K_2	UTILITY KEY SWITCH	LS_2	CHNL-2 MONITOR LOUDSPEAKER	P_1	FIXED "T" PAD 15DB 150 150 Ω	P_6	BRIDGING "T" PAD 10W 15K 150 Ω				

Fig. 6—The scope of the audio facilities incorporated in the CBS 3B studio control console is evident in this block diagram. The facilities permit the simultaneous mixing of program material from nine studio microphones as well as two incoming program lines. Two independent program and monitor channels are employed.

to change and service than are the rack-mounted components that have been used heretofore.

In addition to convenient maintenance and servicing, a completely self-contained studio control console has the additional advantage that complete performance measurements, together with any necessary adjustments or trouble shooting, may be undertaken at the assembly point *prior* to the installation of the unit in the control room. The installation itself is simplified inasmuch as only a minimum number of connections are necessary, no interunit connections being involved. Furthermore, a completely self-contained studio console, by virtue of grouping all components within easy reach of the operator, serves its intended purpose better. Finally, such an arrangement presents a much more attractive appearance.

An earlier broadcast-studio control console incorporating facilities of the scope under consideration was introduced just prior to World War II. This control console has already been completely described.[1] The Columbia Broadcasting System 3B studio control console, which is the subject of the present paper, retains all of the fundamental design principles of the original unit. However, the experience gained during the ensuing years has been employed to achieve an improved arrangement accommodating considerably greater facilities, as well as many new and novel features, in an assembly much smaller in over-all size. Inasmuch as the basic design considerations have already been covered, they will not be repeated at this time. Instead, this paper will be concerned with the new features and methods involved in the design of the new unit.

Attention is called to the fact that a good deal of the story is told in the captions accompanying the figures. This material is not repeated in the text.

Physical Design Considerations

General

The CBS 3B studio control console, shown in Fig. 2, contains, in a relatively small desk-like unit, all the amplifying, mixing, monitoring, and special-effect facilities normally required in the production of large, complex radio broadcasts.

Many of the physical considerations influencing the design of studio control rooms and control consoles already have been outlined.[1] The more important of these considerations include (a) functional placement of all operating controls and visual monitoring facilities, (b) good visibility from the control console into the studio and to other parts of the control room, (c) ready access to all parts for maintenance, (d) adequate ventilation to limit temperature rise of components to safe limits, and (d) an attractive appearance.

[1] H. A. Chinn, "CBS studio control-console and control room design," Proc. I.R.E., vol. 34, pp. 287–296; May, 1946.

Considerable time and careful planning were devoted to the form factor of the CBS 3B console in order that these requirements would be fully met. The preliminary work on this phase of the console design included the construction of several full-scale wooden models, by means of which it was possible to obtain opinions from those concerned with the ultimate operation of the console.

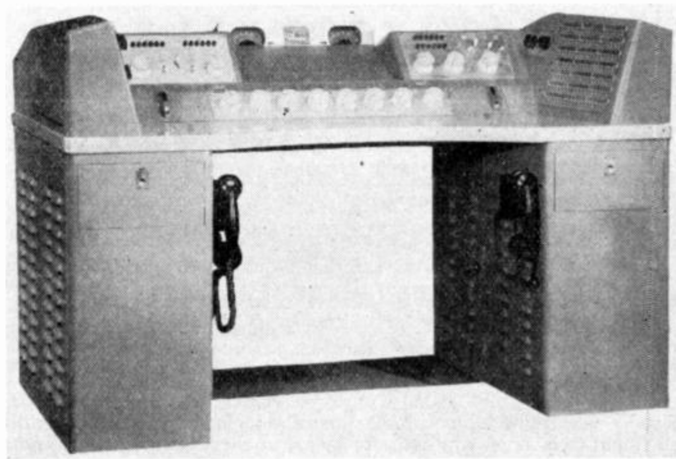


Fig. 2—A front view of the CBS 3B studio control console. Microphone mixer positions 1 to 7 and the Channel 1 master volume control are arranged across the lower portion of the center section. Inasmuch as these controls require almost continuous adjustment during studio rehearsals and air programs, great care was exercised in choosing their spacing, distance above table top, and panel slope to permit long periods of operation with minimum fatigue.

The A and B position mixer controls, together with their associated incoming-line push-button selectors and mixer key switches, are located on the small panel in the center section immediately to the left of the script rack. The microphone mixer key switch is also located on this panel between the A position and B position key switches. The corresponding panel to the right of the script rack contains microphone mixer positions 8 and 9 and the Channel 2 master volume control. Immediately above the two mixer controls are the reverberation push-button selectors which are used when these two positions are employed as reverberation mixer controls. The four key switches above the Channel 2 master volume control are two "utility" key switches, the "channel" key switch, and the "line" key switch.

The audio jack field and "sound-effects" filter occupy the entire panel space on the right wing of the console, while the left wing contains volume controls for the control-room loudspeakers, studio loudspeakers, headphone-cue circuit, and rehearsal-break circuit. The "utility" volume control, rehearsal-break key switch, and telephone dial are also located on this panel space.

Immediately below the table top are two telephone instruments. One is a regular dial extension while the other is a private line direct to the master program distributing center.

The over-all dimensions of this console are 62 inches in length, 34 inches deep, and 39½ inches high.

Single Plugs and Jacks

It would not have been possible to build the CBS 3B console in its final compact form if conventional components and methods had been employed. One example of the departure from convention to achieve compactness was the use of single plugs and jacks in place of the more traditional twin plugs and pairs of jacks which have been used in broadcasting service practically since its inception. Prior to the decision to use these single units, their performance characteristics were carefully investigated,[2] and it was found that, in addition to their smaller space requirements, these single units provided several other advantages over the twin units (see Fig. 3).

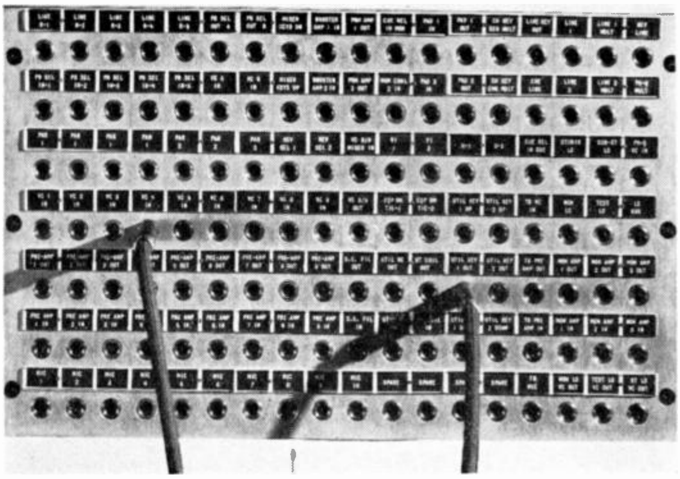


Fig. 3—The application of single plugs and jacks, in place of the traditional twin plugs and pairs of jacks, in the CBS 3B console permitted 126 jack circuits to be mounted on a small panel only 9×14½ inches in size. In a study of the performance characteristics of single plugs and jacks, it was found that, in addition to the smaller space requirements, these units offered several other advantages over the more conventional double units. These advantages included (a) lower cross talk, (b) lower cost, (c) elimination of the possibility of incorrect plug insertion with resultant reversal circuit polarity, and (d) greater ease of plug insertion.

In applying single plugs and jacks to audio jack fields, it is important that the correct type of plug be used. The conventional telephone switchboard type of ring, tip, and sleeve plug is equipped with a long tip element that tends to momentarily short circuit the jack-springs, and consequently the program material, during insertion. An alternate type of ring, tip, and sleeve plug is available that overcomes this difficulty through the use of a shorter tip element and is, therefore, the type of plug that should be used.

Plug-in Amplifiers

Another example of departure from the conventional in achieving small size was the use of very compact amplifier units (see Fig. 4). These two amplifier types, which require but two tube types, were designed expressly for use in the 3B console. However, their performance characteristics are suitable to meet many other amplifier requirements in a modern broadcasting plant. As a matter of fact, with one possible exception, the audio amplifier requirements of an entire plant may be satisfied using none other than these two types of amplifiers. Further, only two types of tubes would need to be stocked to service such a plant.

Script Rack

In the past, a specific space has seldom been provided on studio consoles to accommodate the program script, which is used on practically all radio programs. As a result, the program script usually was placed in the only available space: on the desk directly in front of the operator. This has never been entirely satisfactory, as the

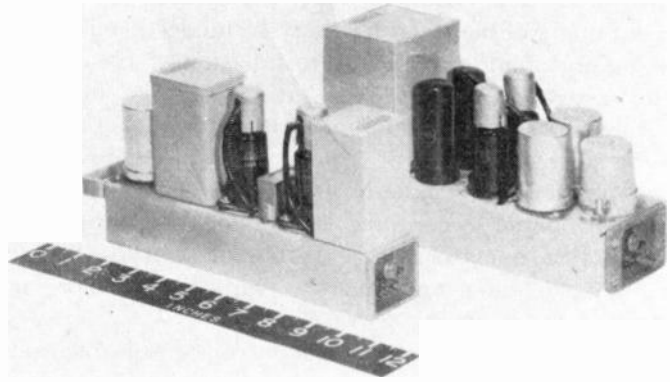


Fig. 4—Only the two amplifier types shown are employed in the CBS 3B console. These amplifiers, in turn, employ only two tube types and, to further simplify maintenance, the amplifiers themselves plug in. The smaller units serve as both preliminary and booster amplifiers, while the larger units serve as both program and monitoring amplifiers.

The preliminary/booster amplifier is 2 inches in width, 10 inches in length, and 5 inches in height. It employs two type-1620 tubes and provides an insertion gain of 40 db, which may be reduced to 34 db (when higher-level microphones become available) by an internal strapping connection. The program/monitoring unit is 3¼ inches wide, 10 inches long, and 5¼ inches high. It employs two type-1620 and two type-6V6 tubes, and provides an insertion gain of 50 db.

An indication of the excellent performance characteristics of these small units may be gained from the over-all performance data of the 3B console as given in the text.

script, under these circumstances, would be partially covered by the arms of the operator. A still greater disadvantage arose from the fact that the operator was required to move his line of vision a relatively large distance from the studio to the script and, with his head turned down, was very likely to miss signals from the performers in the studio.

It had been recognized for some time that the preferred location for the script was in a position directly below the volume indicators set at a convenient angle for easy reading. With the script in this position, the volume indicators, the script, and the studio are all directly in the normal path of vision, requiring no movement of the head, and only a minimum movement of the eyes, to glance from one to the other. Due to other design considerations, in the past this space has generally been employed for operating controls which, for efficient operation, had to be easily accessible.

The form factor of the 3B console was approached with a design prerequisite that a script rack must be provided, and must be located in the preferred position described above. The method by which this was accomplished, and its influence on the appearance of the completed console, can be seen in Fig. 5. The script rack is 12×18 inches in size, large enough to accommodate in open-book fashion the program script, which is printed on standard 8½×11-inch paper. The forward edge of

[2] H. A. Chinn and R. B. Monroe, "Single jacks for broadcast application," *Audio Eng.*, vol. 31, pp. 12–14; July, 1947.

the rack has been depressed to provide an edge to keep the paper from sliding and, in addition, to hold the script at a better reading angle.

The script rack, needless to say, increased the height of the control panel and would have presented a rather serious obstruction to vision into the studio had not the top of the console been sloped toward the rear at the correct angle to minimize the obstruction. It is necessary, of course, also to slope the sill of the control-room

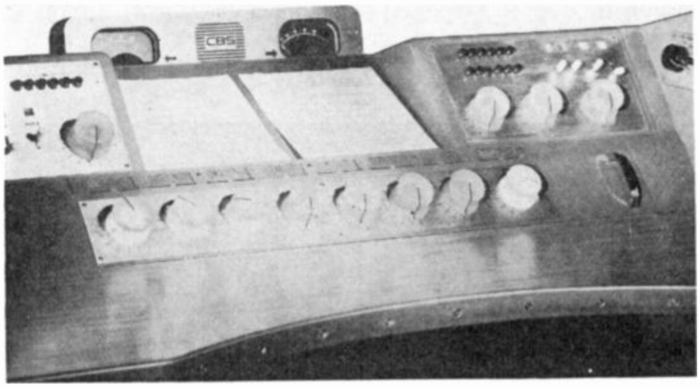


Fig. 5—A close-up of the center section of the mixer control panel showing the control knobs which light up when the mixer channel is in use. Two devices have been employed on this mixer panel to eliminate a former practice of marking the panels with pencilled notes and setting marks. The first are the small "magic-slate" writing pads mounted above each mixer control. These writing pads permit the operator to make temporary markings to identify the artist or group using the associated microphone. Markings may be removed quickly and easily by merely lifting the clear-plastic top sheet. The second device is a control-knob setting indicator; a disk of clear plastic the same diameter as the skirt of the knob which is provided with a protruding indexing marker. This indicator is mounted between the control knob and panel and may be rotated until the indexing marker indicates the desired knob setting, established during rehearsals. The protruding indexing marker can be felt as the control knob is advanced, making it unnecessary to use the eyes in setting the control knobs to the desired point.

Immediately above the script rack is a panel containing the two volume indicators and the rehearsal-break microphone which is mounted behind the center grillework. This entire section has been made plug-in for the purpose of expediting maintenance of the unit.

At the side of each volume indicator are arrow-shaped red-plastic indicators which light up to indicate the channel in use. These indicators are so interlocked with the "line," "channel," and "mixer" key switches that they light only when all switches are in the proper "on-the-air" position.

It will be noted that an experimental black scale (contrary to the ASA standard) is employed on each of the volume indicators. This was done in order to gain experience with a new type of volume-indicator illumination for potential use in darkened television control rooms. The divisions and lettering on these black scales are made with paint containing a fluorescent material which glows under the influence of ultraviolet light. The meter pointer is coated with the same material. Small ultraviolet lamps are mounted directly beneath the volume indicators with the light entering the meter enclosure through an opening in the bottom of the meter case. The fluorescent markings glow green on the scale range up to the reference point, while the markings above the reference point glow in red.

It is important that the ultraviolet light, which in this case is obtained from a small-size fluorescent lamp, be operated from direct current. If a.c. operation is attempted, a stroboscopic effect occurs as a result of the fast movement of the meter pointer in the fluctuating light field.

window to obtain the maximum benefit of this expedient. This same method of improving visibility was also applied to the top of each of the two wings, which were also sloped to increase the operator's visibility to either side of the console.

Mixer-Channel-in-Use Indicators

In past studio-console design, it has been customary to associate a small pilot light with each of the mixer controls for the purpose of visually indicating the mixer channels in actual use. This pilot light has usually been mounted behind a small panel indicator which was located in close proximity to the appropriate mixer control.

A different and unusual approach to this design detail has been incorporated in the 3B console. Instead of employing small pilot-light indicators, the large control knob of each mixer control has been designed to light up when that particular channel is in use, thereby making the knob itself serve as a large, easily visible "channel-in-use" indicator. This is accomplished through the use of clear-plastic control knobs with a frosted finish, Fig. 5. Lamps are mounted behind the knobs (and panel) in such a manner that the light passes through the knob and causes the frosted surface to glow with an even distribution of light over the entire knob. With such a positive, unmistakable indicator there is little likelihood of the operator failing to observe which mixer channels are in use.

The light circuits associated with the illuminated knobs are controlled by a small switch which is built into the associated mixer volume control. This switch is actuated by the mechanical rotation of the mixer control in such a manner that the light is off when the mixer control is in the "off" position but is lighted as soon as the mixer control is advanced a few degrees. The lamps themselves are low-voltage pilot lights and are operated from a.c. to conserve the drain on the self-contained low-voltage d.c. supply. No difficulty with hum is experienced due largely to the careful arrangement of circuit wiring.

Pilot Lights

Another significant design detail of the 3B console, which aided in achieving the clean-cut, uncluttered front-panel appearance, is the use of a single signal-lamp indicator above each key switch. This indicator visually signals the setting of a key switch by displaying a color which is a function of the position of the switch. As an illustration, the "line" key switch may be set to three different positions and, in the past, three separate panel indicators of different color have been used to indicate the setting of this switch. In the 3B console, a single window is located above the line switch. This window lights up green when the switch is in the "up" position, amber in the "center" position, and red in the "down" position. This change of color is accomplished by utilizing the property of clear plastic to conduct and, when properly angled, to reflect light rays. Three clear glass lamps, each mounted behind a colored plastic filter are employed. A suitably shaped block of clear plastic guides the light from the lamp which is lighted and reflects this light through the window in the front panel.

Component Standardization

The reduction of the total number of tube types to only two, greatly simplifies the problem of stocking spare tubes for the 3B console. This standardization of components was practiced in every possible case. For example, only two amplifier types are employed. In addition, the same type of plug and receptacle are employed on all plug-in amplifiers and plug-in power supplies, as well as the plug-in volume-indicator turret. Furthermore, only one type of volume control is used throughout. Attention to small details such as these pays dividends by reducing the time spent in maintenance of the unit.

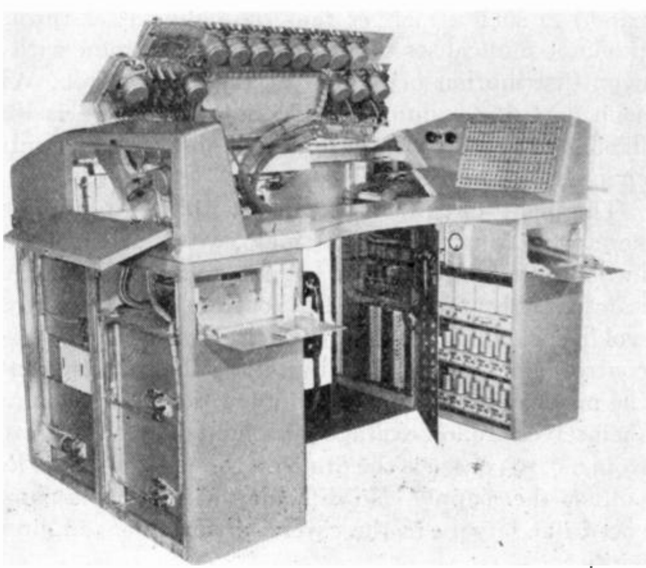


Fig. 7—A view of the CBS 3B studio control console with all access doors as well as the center control panel opened. This view shows how readily all components may be reached for inspection and servicing.

The two pedestals of the console serve as equipment compartments. The forward section of the right-hand compartment contains all audio amplifier units as well as a "glove" compartment for the storage of spare tubes, program scripts, pencils, and other miscellaneous items. The rear section of this compartment contains the audio transformers, audio relays, audio terminal blocks, and resistance attenuation networks.

The power equipment is housed in the left-hand equipment compartment. The forward section of this unit contains two plug-in power supplies which provide amplifier plate power. The upper section contains a power panel, accessible through a small door in the front of the unit. A master "on-off" magnetic circuit-breaker switch, as well as regular-emergency a.c. supply and regular-emergency low- and high-voltage-supply transfer toggle switches are mounted on this panel. The rear section of this compartment contains a 24-volt d.c. power supply for operation of relays and pilot lights, two filament-lighting transformers, and "on-the-air" sign relays.

All power-supply rectifiers are of the selenium type, no rectifier tubes being employed.

Electrical Design Considerations

General

Despite the small dimensions of the CBS 3B console, the audio facilities incorporated in it exceed by far those in any present broadcasting console of comparable size. As has already been described, this was made possible through the use, wherever possible, of small-size components, as well as by careful arrangement and packaging of all components. A block diagram showing the scope of the facilities provided in this console is given in Fig. 6. "Opened-up" views are shown in Figs. 7, 8, and 9.

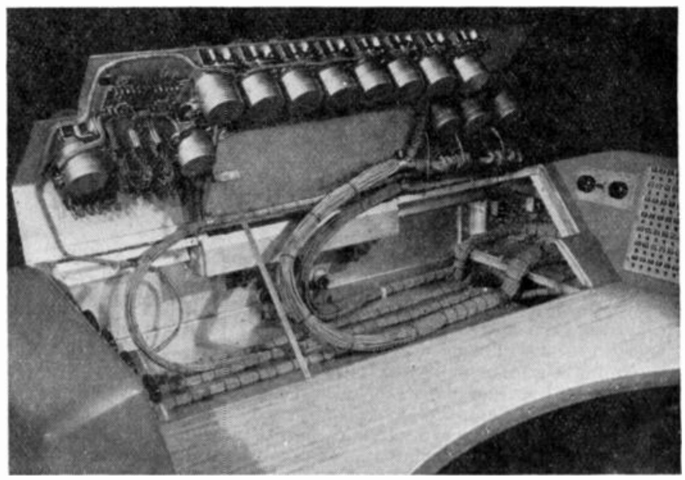


Fig. 8—The center control panel of the 3B console swings upward to provide access for inspection and maintenance of the volume controls and other panel-mounted components.

A portion of the audio wiring is visible in this view. The individually shielded and insulated pairs of wire can be seen laced into cables. To keep cross talk at the lowest possible value, these cables have been segregated into four different categories: (a) low level—below minus 20 vu; (b) medium level— minus 20 vu to plus 20 vu; (c) high level—above plus 20 vu; and (d), control circuits.

The large cable loops, by means of which the wiring is carried to the hinged control panel, are also visible. These loops are formed, laced, and secured in a manner that minimizes any bending of the cable as the panel is opened and closed.

The lower portion of the small d.c.-operated fluorescent lamps which provide black light for volume-indicator illumination can be seen near the center of the back wall.

Mixer and Associated Circuits

An eleven-position mixer, which permits the simultaneous mixing of nine microphone channels and two incoming-program line channels (known as the "A" and "B" channels), is provided. Program material to these latter two channels may be selected from any one of five sources by means of mechanically and electrically interlocked push-button selectors. Each of the incoming line channels are provided with a transformer which serves to isolate the balanced-to-ground program line from the one-side-grounded mixer circuit. In addition, there is a resistance attenuation pad which establishes the correct volume levels and also serves to isolate the mixer circuit from any impedance variations presented by an incoming-program line.

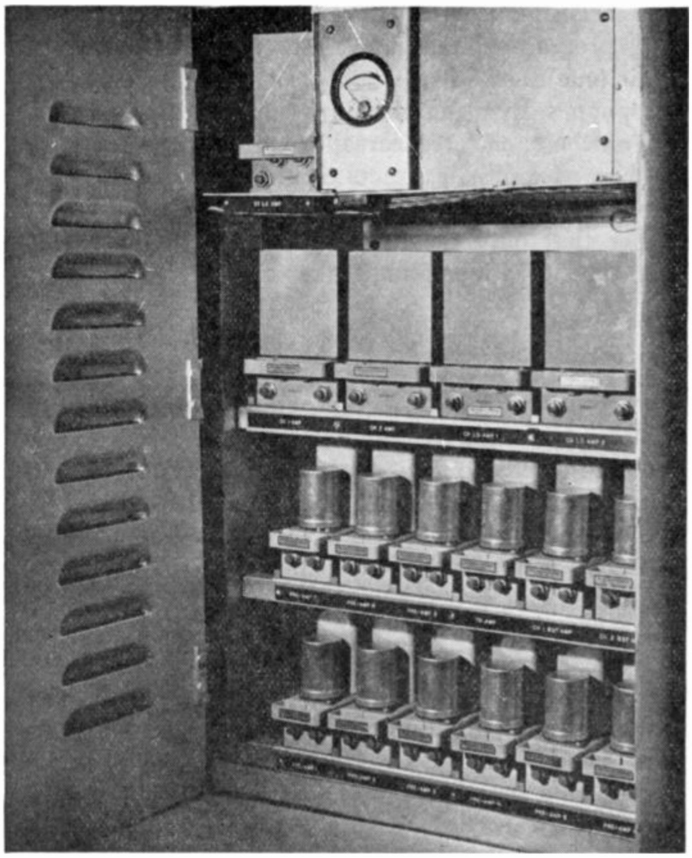


Fig. 9—A closeup showing the twelve preliminary/booster and five program/monitoring amplifier units in the forward section of the right-hand equipment compartment. The plate current of any tube may be checked by means of the push buttons mounted on the individual amplifier units. The relative plate current is indicated on the meter in the upper portion of the photograph.

Each microphone channel includes a preliminary amplifier, which serves to amplify the extremely low microphone output voltage prior to mixing, and a variable bridged-tee type of attenuator which serves as the mixer control. The outputs of the various microphone channels are combined by means of a differential network[3] which provides correct termination and source impedances for all circuits involved.

It will be noted that two of the microphone channels (positions 8 and 9) are combined prior to reaching the main eight-position differential network by means of a two-position differential network. This arrangement permits these two channels to serve as an "auxiliary" two-position mixer. One important use of this auxiliary mixer is in conjunction with the reverberation selectors, the operation of which is described in a following section.

The auxiliary two-position mixer may be used for other utility purposes; for example, a portion of a program utilizing two microphones may be balanced on these two channels and this balanced program material then gained on one of the regular mixer controls without disturbing the program balance. In this case, the mixer control would be, in effect, a "submaster" volume control.

An innovation in the design of these facilities is the omission of microphone key switches on the individual microphone channels. These key switches were omitted after a survey showed that the operating personnel were of the opinion that their omission would tend to smooth the continuity of program production, as each microphone channel must, by necessity, be faded in and out. As a result, a single key switch controlling all nine microphone channels simultaneously is employed. A second mixer key switch controls the "A" line position, and a third controls the "B" line position.

Regular and Emergency Program Channels

Two complete program channels have been provided in the CBS 3B console. Program material from the mixer key switches is connected to Channel No. 1 by throwing the desired switch to the down position and to Channel No. 2 by throwing the desired switch to the up position. This arrangement requires that a separate three-position differential network be provided on the input of each of the two channels.

Channel No. 1, the regular channel, contains a booster amplifier, master volume control, program amplifier, volume indicator, and line pad. A bridging transformer connected across the input of the line pad supplies a sample of the program material from this channel to the regular aural monitoring facilities. Channel No. 2 is identical to the regular channel including not only a separate volume indicator for visual monitoring but also separate and independent aural monitoring facilities. Either of the two program channels may be connected to the outgoing-program line by means of the "channel" key switch.

Channel No. 2 may be used to perform any of the following functions:

1. An "emergency" channel. In the event of an equipment failure in any component of the regular channel, a complete new channel can be substituted by throwing the "mixer" key switches and the "channel" key switch to the "up" position. This not only provides a new program channel but also a new volume indicator, monitoring amplifier, and monitor loudspeaker.

2. A "test" channel for lining up the level and prechecking the quality of any portion of a program prior to putting it on the air. This is accomplished by throwing any of the three mixer key switches to the "up" position. When this is done, the level of the program material may be set on the Channel 2 volume indicator and the program itself may be heard on the Channel 2 loudspeaker. Monitoring of the air channel will not be interrupted.

[3] In the past, the term mixing network or mixer-matching network has sometimes been applied to this circuit. Nonreactive dividing networks of this type are used extensively for other purposes, e.g., for distributing a single signal source to several loads. The term "differential network" is less restrictive and more general for this type of circuit.

3. A "utility" microphone-to-line or loudspeaker channel. Such a utility channel is often useful in obtaining unusual program effects. A built-in sound-effects filter may be patched into the circuit as desired by means of patchcords.

Rehearsal-Break Facilities

Rehearsal-break or talk-back facilities are provided to permit communications between the control room and studio during rehearsals. By means of these rehearsal-break facilities, it is possible for the program director in the control room to "break" or interrupt the performers during a rehearsal in order to give instructions or otherwise direct their performance.

Two rehearsal-break microphones and key switches have been provided, one set on the 3B console, the other on the associated program directors desk. It will be noted from inspection of the block diagram, Fig. 8, that the operation of the rehearsal-break facilities is entirely independent of the settings of all volume controls in the remainder of the circuit. The operation of these facilities are interlocked with the "line" key switch as described below.

Line Key Switch

A standard CBS three-position line key switch is employed. The "rehearsal" position (up) of this switch is used during studio rehearsals. In this position the output of the program channel is terminated in a resistor and energizing voltage is made available to the rehearsal-break relay, permitting full use of the rehearsal-break facilities. The "cue" position (center) of the line key switch is used just prior to placing a program on the air in order to listen to the closing portion of the preceding program from which the starting cue is obtained. This cue will be heard on the studio, sub-studio, and control-room loudspeakers. In the "air" position (down) of the line key switch, program is transmitted to the master program distributing center and the normal rehearsal-break facilities become inoperative to preclude their accidental use while the studio is on the air. However, the circuits have been so arranged that communication to the studio is still possible under these circumstances. If the rehearsal-break facilities are used with the line key in the "air" position, instructions may be given to any person in the studio wearing headphones connected to the headphone-cue (PH-Q) circuit.

Monitoring Circuits

The aural monitoring circuits of the 3B console, except for the fact that a complete second channel is provided, follow conventional lines.[4] Briefly, three different sources of material are available to the monitor circuits: (1) program material at the output of program channel 1, (2) program material from the studio which is on the air (cue), and (3) the output of the rehearsal-break microphones. By means of relays energized through contacts on the "line," "rehearsal-break," and "mixer" key switches, as well as contacts on the relays themselves, the various monitor circuits are interlocked in such a manner that only the desired material will be reproduced on the various loudspeaker units.

Reverberation Facilities

In the production of radio programs, especially those of a dramatic nature, program sequences are often encountered where, to achieve the desired effect, it is necessary to create the illusion of greater-than-normal reverberation. Furthermore, it is often necessary to alter the degree of reverberation during the progress of the scene when this is necessary to achieve the desired effect.

Devices by means of which the effect of increased reverberation may be created, such as reverberation chambers and synthetic reverberation devices, have already been described.[5–9] However, the methods by which such a reverberation device is employed in association with the CBS 3B studio console to achieve the required reverberation control may prove of interest.

Reverberation effects are normally employed on one, and upon occasion two, microphone channels. In the 3B console, two reverberation push-button selectors are provided permitting a bridging transformer connection to be made across the input of the mixer control of the microphone channel or channels to which reverberation is to be added.

In the interest of economy and maximum utilization of facilities, the circuits of the 3B console are arranged in such a manner that the amplifiers and volume controls constituting the reverberation channel are normally arranged to function as microphone channels 8 and 9. This is done inasmuch as reverberation effects are not required on all programs and the reverberation channel, instead of remaining idle, is made available for use as additional microphone channels. When the reverberation facilities are to be used, three patchcord connections are made as indicated on the block diagram of Fig. 6. The number of available microphone channels under these conditions is reduced to seven.

The microphone channel or channels selected for reverberation by means of the push-button selectors are transmitted to the reverberation device, usually some

[4] H. A. Chinn, "Broadcast studio audio-frequency systems design," Proc. I.R.E., vol. 27, pp. 83–88; February, 1939.

[5] J. K. Hilliard, "Reverberation control in motion picture recording," *Electronics*, vol. 11, p. 15; January, 1938.

[6] H. A. Chinn, "Reverberation control in broadcasting," *Electronics*, vol. 11, pp. 28–29; May, 1938.

[7] S. J. Begun and S. K. Wolf, "On synthetic reverberation," *Communications*, vol. 18, pp. 8–9; August, 1938.

[8] P. C. Goldmark and P. S. Hendricks, "Synthetic reverberation," Proc. I.R.E., vol. 27, pp. 747–752; December, 1939.

[9] M. Rettinger, "Reverberation chambers for rerecording," *Jour. Soc. Mot. Pic. Eng.*, vol. 45, pp. 350–357; November, 1945.

distance away, by means of a suitable program line. The level of this transmission may be controlled by means of the mixer controls of the two-position reverberation mixer. At the same time, the program material also passes on into the program channel in the normal manner, this level being a function of the setting of the mixer control of the channel involved. The output of the reverberation device returns to the console on one of the five incoming-program lines (known as the reverberation return line) and from this point it is introduced into the program channel, the level being under the control of the mixer control (A or B) involved. The desired reverberation effect is obtained by the adjustment of the relative proportions of the original and reverberated signal, which in turn is controlled by the respective settings of the microphone channel and reverberation return mixer controls. Often, unusual effects are obtained by combining the use of a reverberation device and a sound-effects filter (see Fig. 10).

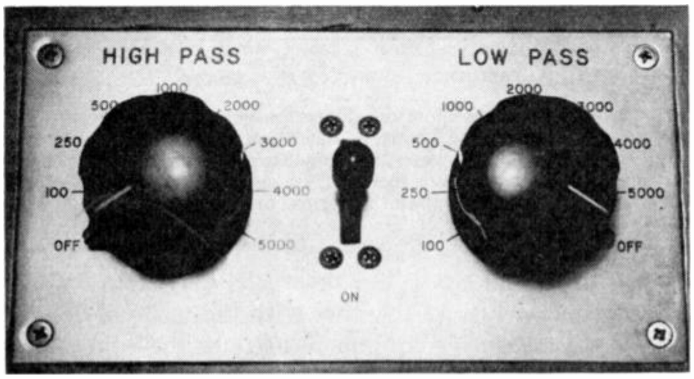


Fig. 10—The CBS "sound-effects" filter is a simple, yet effective device for obtaining special effects in program production. By suitable modification of the normal response-versus-frequency characteristic of the program channel through the use of this filter, telephone conversations, police and airways radio circuits, as well as effects such as ghostly voices, may be readily simulated.

The filter consists of a low-pass section and a high-pass section connected in cascade. The cutoff frequency of each section is independently adjustable, a choice of any one of eight frequencies (100, 250, 500, 1000, 2000, 3000, 4000, and 5000 c.p.s.) being available. In addition, the individual sections may be removed entirely from the circuit. Therefore, the unit can be used either as a high-pass, a low-pass, or a band-pass filter.

Each filter section is a single-prototype or constant-K section, and may be either of pi or tee configuration. For reasons of economy, it is often desirable to employ a pi section for the low-pass unit and a tee section for the high-pass unit, this arrangement requiring the minimum number of inductors. In the above unit, the Q of the coils is sufficiently high to provide attenuation at a rate of 18 db per octave until at least 60 db attenuation has been obtained. The insertion loss in the pass band is less than 1 db.

To insure against switching noises during operation of the range switches, the capacitors in the various sections are shunted with suitable resistors to provide a continuous discharge path. Furthermore, the switching arrangement is such that, in passing from one set of contacts to the next, continuity of the signal through the filter is maintained, thereby avoiding any program breaks if adjustments are made during a broadcast.

The sound-effects filter is usually employed in one of the microphone channels, being patched between the preliminary amplifier output and the mixer control input. Owing to the low level existing in these circuits, the unit is well shielded and employs hum-bucking coil construction to prevent pickup from stray electromagnetic fields.

Sound-Reinforcement Feeds

In large broadcast studios and radio theaters, where a studio audience is present during the presentation of radio programs, it is usually essential to provide sound-reinforcement facilities[10] to enable the studio audience to hear all portions of the program in proper perspective.

Effective sound reinforcement requires that only those portions of the program which could not otherwise be easily heard by the studio audience be reproduced on the studio loudspeakers. For this reason, a separate mixing console and operator are usually employed for the specific purpose of preparing the program material for sound reinforcement, and properly controlling the over-all loudspeaker levels during the performance. A preferred location for the sound-reinforcement mixer is in the audience section of the studio, where the operator has first-hand knowledge of the degree of reinforcement required and the immediate result of all operating adjustments.

When a sound-reinforcement system such as described above is employed, it is necessary to make available to this sound system a sample of the program material from each of the mixer channels of the studio control console. Such sound-reinforcement feeds have been made available in the 3B console through the use of resistance attenuation networks with a high input impedance which are bridged across the input of each of the mixer volume controls. The program samples thereby obtained from each mixer channel prior to any volume adjustments are fed to the sound-reinforcement mixer through a suitable multiconductor cable.

Utility Facilities

In addition to the basic facilities already described, the CBS 3B console is equipped with various utility facilities, not normally connected into the circuit, which are available for use when some special operating requirement arises which makes their use essential. These utility facilities may be inserted into any desired program circuit by means of patchcord connections.

The utility facilities include a "sound-effects" filter (Fig. 10) which is usually connected in a microphone channel when it is desired to simulate a telephone conversation or other effects requiring a restricted frequency range. Other utility facilities include a variable bridged-tee attenuator equipped with isolation transformers on both the input and output in order that it may be used with either balanced-to-ground or unbalanced-to-ground circuits; two utility double-pole double-throw key switches; a utility bridging transformer; and two sets of parallel-connected jacks.

In addition to the utility facilities outlined above, several program circuits of utility nature have been provided for in the 3B console. These include a spare or emergency program line to the master program distribu-

[10] H. A. Chinn and R. B. Monroe, "Broadcasting studio sound reinforcement," *Audio Eng.*, vol. 31, pp. 5, 37–38; December, 1947.

tion center for use in the event of a failure of the regular program line; two tie lines to an equipment room for use should it be necessary to pick up the input and output terminals of a special unit of equipment; two general utility circuits to the studio and sub-studio as well as a similar circuit to the studio "utility" room. In addition, there are headphone-cue (PH-Q) circuits to the studio, sub-studio, and utility room.

Circuit Impedance

It will be noted from the block diagram (Fig. 6) that a circuit impedance of 150 ohms has been employed throughout in these facilities. The use of this low circuit impedance, which is in accordance with the latest RMA proposed standards, assists greatly in achieving uniform response-versus-frequency characteristics at the higher audio frequencies.

PERFORMANCE

The measured performance characteristics of the CBS 3B studio control console are well within the requirements dictated by good engineering practice and readily meet the Federal Communications Commission requirements for a.m., f.m., and television-sound broadcasting service. Measurements were made from the input of the microphone preliminary amplifiers to the output of the line pad, and also to the output of the monitoring amplifiers. All gain controls were set to their normal operating adjustments, the insertion gain of the program channel being 70 db under these conditions.

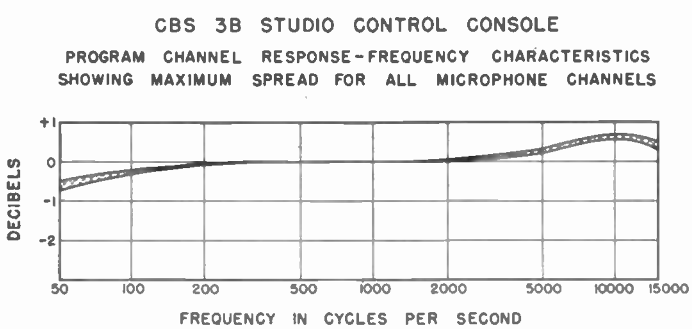


Fig. 11—The curve above shows visually the response-versus-frequency characteristics of the complete program channel of the CBS 3B console. From these data it may be seen that the performance is well within the requirements set forth for a.m., f.m., and television audio facilities.

The signal-to-noise ratio of the complete program channel ranges from 73 to 75 db, as detailed in the text.

The response-versus-frequency characteristic of the program channel is uniform, within 0.7 db of the 1000-c.p.s. value, from 50 to beyond 15,000 c.p.s. Fig. 11, which shows the extreme values measured, indicates the high degree of uniformity between channels. The response-versus-frequency characteristic through the monitoring channel (including the program channel) is substantially equivalent to that of the program channel.

The single-frequency harmonic distortion of the program channel, measured at an output level of +20 dbm (which is 10 db greater than the normal program output level of +10 vu), is less than 0.2 per cent from 100 to 15,000 c.p.s., and less than 0.4 per cent in the region from 50 to 100 c.p.s. The distortion through the monitor channel (including the program channel), measured at an output level of +38 dbm, is less than 0.75 per cent from 50 to 10,000 c.p.s., and less than 1.0 per cent from

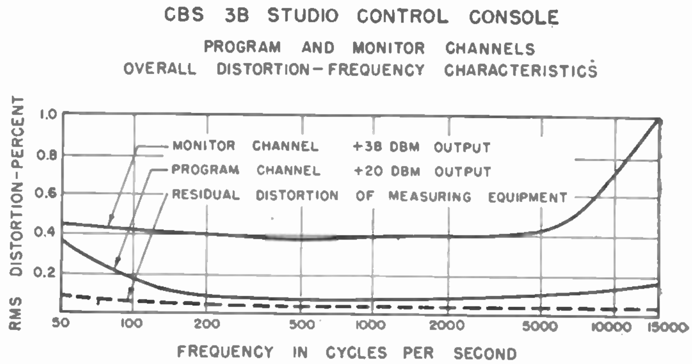


Fig. 12—These curves show the distortion-versus-frequency characteristics of the CBS 3B console. Attention is called to the very low distortion in the complete program channel. These program channel measurements were made at an output level of +20 dbm, which is 10 db higher than the normal program level.

10,000 to 15,000 c.p.s. The measured distortion values are plotted on Fig. 12 together with the residual distortion of the measuring equipment used for these measurements.

The signal-to-noise-ratio measurement was made in accordance with established CBS practice.[1] Using this method, the signal-to-noise ratio is expressed with respect to a single-frequency test tone 10 db higher in level than the normal program level. The signal-to-noise ratio of the various channels, when measured in this manner, was found to range from 73 to 75 db.

ACKNOWLEDGMENT

As is the case with any project of this nature, its completion would not have been possible without the contributions and suggestions of many persons. Unfortunately, it is not practical to attempt to mention each person and his contributions. However, all are sincerely appreciated.

An outstanding acknowledgment is made to Howard A. Chinn, chief audio engineer of the Columbia Broadcasting System, under whose direction this project was undertaken. Without his inexhaustible contributions, suggestions, and collaboration, the final design, as described herein, would not have been possible.

Restricted-Range Sky-Wave Transmission*

J. E. HACKE, JR.†, AND A. H. WAYNICK†, SENIOR MEMBER, I.R.E.

Summary.—**This paper reports results of a study showing that it should be feasible to restrict considerably the range within which radio signals may be received after reflection from the *E* layer of the ionosphere. This is accomplished by proper choice of operating frequency and by using a relatively simple directive array beamed vertically upwards. Other types of arrays, and other operating frequencies, are discussed for comparison.**

INTRODUCTION

THE ROLE OF the ionosphere in the long-distance transmission of radio waves in the frequency range of about 1 to 30 Mc. is well known. Under midday conditions, radio waves vertically incident on the ionosphere are refracted back from the lower, or *E* layer, of the ionosphere, for frequencies up to 4 Mc. This layer has an ionization maximum at a height of about 120 km. From ionosphere-earth geometry, waves refracted obliquely from this layer are known to have a maximum "one-hop" range of about 2000 km. For the frequency range of about 4 to 10 Mc., radio waves directed vertically upwards are refracted from the upper, or *F* layer, with an ionization maximum at a height of about 300 km. Waves refracted from this layer are known to have a "one-hop" maximum range of about 4000 km.

The above frequency figures apply, approximately, for midsummer noon and in middle latitudes. The maximum frequencies and heights vary in a relatively predictable manner with solar time, season, and latitude. The indicated values for maximum "one-hop" range, however, being dependent only on the geometry, and therefore upon layer heights, remain fairly constant for the *E* layer and very roughly constant in case of the *F* layer.

The use of this frequency range has numerous advantages. These include antenna structures of reasonable size and relatively high efficiency, low static noise level in comparison with lower frequencies, and reasonably small transmitter-power requirements. However, the relative narrowness of this frequency band, and the great demand for long-range circuits, has prevented use of this frequency band for comparatively short-range transmission, due to the interference that would result. This applies particularly to omnidirectional transmissions. The present study was undertaken, therefore, in an effort to determine the feasibility of restricting the range of such transmissions by means of a vertically directive transmitting antenna system.

* Decimal classification: R112.4. Original manuscript received by the Institute. The work reported in this study was done under a research contract, W28-099-ac-143, between The Pennsylvania State College and the Watson Laboratories, Air Matériel Command, Red Bank, N. J. Presented, joint meeting, U.R.S.I., American Section, and I.R.E. Washington Section, Washington, D. C., May 3, 1948.

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In the following preliminary work, numerous simplifying assumptions are made. In particular, the effect of the earth's magnetic field on the ionosphere is neglected. This is roughly equivalent to confining attention to the ordinary component of the sky-wave field. In addition, absorption in the ionosphere is not considered. This assumption results in maximum-range conditions, since daytime absorption in the ionosphere will reduce the range obtainable in comparison with the no-absorption value.

Throughout this study, results are compared with calculated results using a single horizontal dipole, one-half wavelength long and one-fourth wavelength high. This antenna forms the unit in the arrays and is referred to throughout as "the single-dipole antenna."

Attention is confined to two frequencies: (1) below the midday vertical-incidence *E*-layer critical frequency; and (2) approximately midway between the above and the *F*-layer vertical-incidence critical frequency. Vertically directive arrays are then determined which restrict the range of sky-wave transmission to stipulated values. It is shown that a considerable restriction in range appears to be practical for the first frequency.

II. FREE-SPACE DIRECTIVITY OF A HALF-WAVE DOUBLET

The starting point in the determination of ground- and sky-wave ranges involves the determination of the free-space radiation pattern of a half-wave doublet. This result is well known,[1] and is here written in terms of a *free-space directivity factor* D_f:

$$D_f = [1 - \sin^2 \xi \cos^2 \psi]^{1/2}. \quad (1)$$

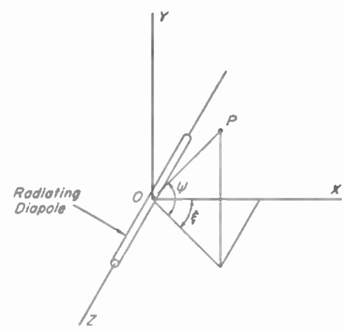

Fig. 1—Co-ordinate system for free-space directivity factor:
OXZ = "ground" plane
OXY = "equatorial" plane
OYZ = "antenna" plane.

[1] F. E. Terman, "Radio Engineers' Handbook," McGraw-Hill Book Co., New York, N. Y., 1943.

This equation is written in terms of a spherical coordinate system with the origin at the center of the antenna and with the azimuth angle ξ and the vertical angle ψ defined as in Fig. 1. It will be noted that when $\xi=0$, $D_f=1$, and maximum radiation therefore takes place in this plane.

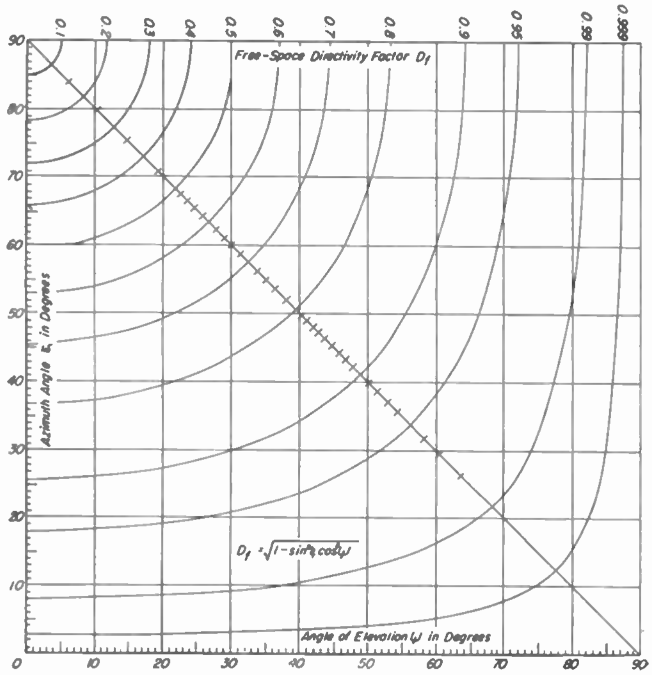

Fig. 2—Contour diagram giving the free-space directivity D_f as a function of elevation angle and azimuth angle, illustrated in Fig. 1.

A contour diagram which is convenient in making practical use of this relation appears in Fig. 2. Here contours of D_f are plotted as functions of ξ and ψ, so that the value of the former may be readily obtained by interpolation for any given value of the latter.

III. Equatorial Directivity of a Half-Wave Horizontal Doublet

In practice, the radiation pattern of interest is that of a horizontal half-wave antenna a finite distance above the surface of the earth. To obtain this, as is well known, it is necessary to consider the "image" antenna induced in the earth by the transmitted energy directed towards the earth. By confining attention to the equatorial plane of the antenna, the condition for maximum range is obtained. The result is a relatively simple expression for what is here called the *equatorial directivity factor*[2] D_r:

$$D_r = 1 + R' \exp\left[j(4\pi h/\lambda)\sin\psi\right]. \qquad (2)$$

In this expression,

h = antenna height above the earth's surface

λ = wavelength in the same units as h

ψ = angle of elevation above the earth's surface

R' = complex reflection coefficient of the earth $\equiv \rho \exp(j\xi)$

$$\rho = \frac{\left[\sin^4\psi + L^2 - 2L^2\sin^2\psi\cos 2m\right]^{1/2}}{\sin^2\psi + 2L\sin\psi\cos m + L^2}$$

$\xi = \tan^{-1}(2L\sin\psi\sin m)/(\sin^2\psi - L^2)$

$L = \left[(\cos^2\psi-\epsilon)^2 + 4\sigma^2/f^2\right]^{1/4}$

$m = \frac{1}{2}\tan^{-1}(2\sigma/f)/(\cos^2\psi - \epsilon)$

ϵ = dielectric constant of the earth in e.s.u.

σ = conductivity of the earth in e.s.u.

f = frequency in c.p.s.

It is intuitively evident that maximum radiation upwards without the presence of lower side lobes is obtained for an antenna height of about $\lambda/4$. Fig. 3 is a

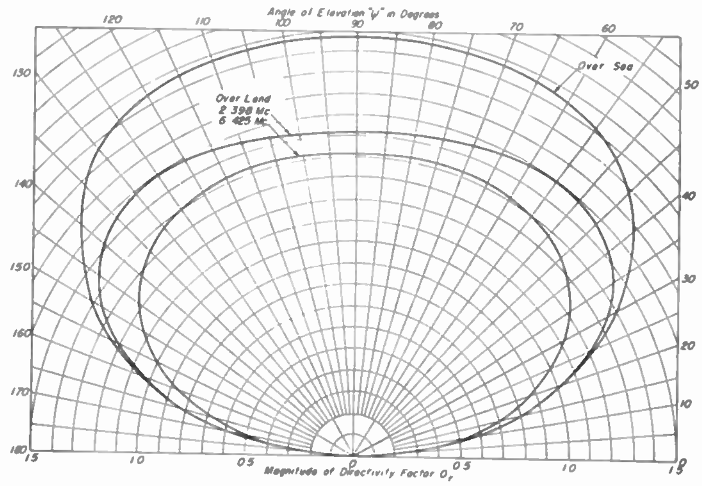

Fig. 3—Magnitude of equatorial directivity D_r for a single horizontal dipole above the earth. Earth constants assumed are noted in the text.

plot of D_r for this height and for the frequencies of interest, for both overland and oversea transmission. The overland curves are calculated assuming $\epsilon=5$ and $\sigma=10^{-14}$; the oversea curves are calculated assuming $\epsilon=81$ and $\sigma=3.8\times10^{-11}$.

The radiation efficiency of this antenna is large even for relatively low elevation angles, so that but little advantage is gained in restricting the range by reducing the low-angle radiation with this simple vertically directive system. It should also be noted that the field at any distance $2r$ from this antenna is equal to

$$E = \frac{M}{2r} D_f D_r \qquad (3)$$

under the conditions that $2r$ is many wavelengths and that the receiver is several wavelengths above the earth, since the guided wave has been neglected. The field intensity is given in microvolts per meter per kilowatt radiated, when $2r$ is expressed in meters, and the dipole moment M is given in microvolts per kilowatt. M has

[2] G. W. Pierce, "Lecture Notes in Physics 23," Engineering 223, Harvard University, 1936. Mimeographed manuscript.

been calculated to be 2.215×10^8 microvolts per kilowatt.[3]

IV. Ground-Wave Field Versus Range

Determination of the range from the transmitting position wherein the ground wave is of appreciable magnitude is essential for two reasons. In the first place, near the outer edge of this range lies a region wherein both sky- and ground-wave signals are of approximately equal amplitude; and, consequently, fading results. Secondly, if the operating frequency is slightly above the vertical-incidence ionosphere-layer critical frequency, the sky-wave skip range exceeds zero and, as an outer limit, should be held to values less than the ground-wave range in order that there be no region within the desired range wherein no signals are received.

The method of calculating the ground-wave ranges for the frequencies of interest has been adequately covered elsewhere.[4] Curves showing the results of these calculations for the transmitting antenna described above are shown in Fig. 4. These curves are based on the

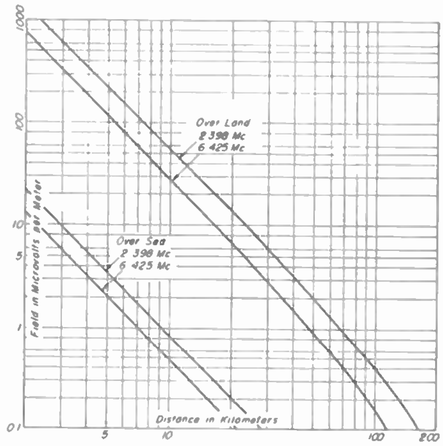

Fig. 4—Ground-wave field intensity at the surface of the earth as a function of range for the antennas of Fig. 3. Equatorial plane of the antennas. Average atmospheric conditions assumed. 1.0 kw. radiated.

same constants as those used in Fig. 3. The curves apply for points on the intersection of the earth's surface and the equatorial plane of the antenna. For other azimuth angles ξ, less than about 80°, similar curves may be obtained by multiplying the ordinates by $\cos \xi$.

When the ground-wave field is to be determined for points above the earth's surface, it is further necessary to consider the height of the receiving antenna above the surface of the earth. Below the line of sight, this factor is easily accounted for by the curves of Fig. 5. Thus, for a given range, the field at any height h may be determined by multiplying the relevant value given in Fig. 4 by the relevant ordinate in Fig. 5.

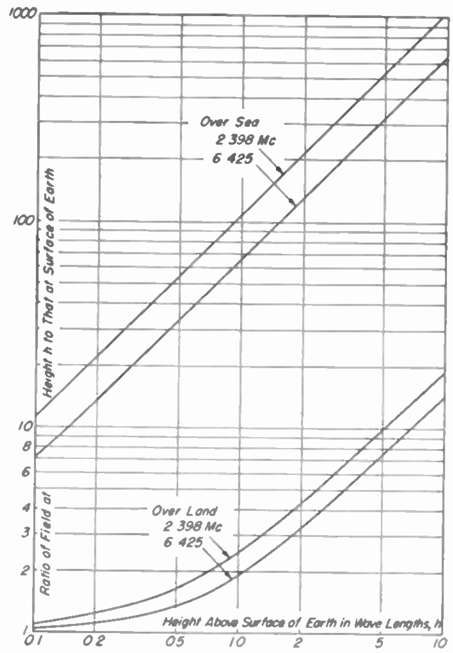

Fig. 5—Height-gain characteristic for the ground-wave field below the line of sight. Constants as in Fig. 3.

V. Calculation of Sky-Wave Field Versus Range

Fortunately, for the purpose of this paper, it is not necessary to attempt to deal with exact expressions describing the characteristics of the ionosphere. The following simplifying assumptions have been made to obtain a tractable analysis:

1. A plane ionosphere and curved earth are assumed. This involves the assumption that the height of reflection is independent of the angle of incidence.

2. The earth's magnetic field is neglected, so that the analysis applies, approximately, to the ordinary sky wave.

3. Absorption in the ionosphere is neglected. This effect may, very roughly, be included from curves published elsewhere.[5]

4. Reflection takes place from one layer. Thus, the possible effects of sporadic E are ignored when F-layer reflection is assumed.

5. For multielement antenna structures, the effects of coupling between the elements are not considered.

Under the above assumptions, and confining initial attention to the equatorial plane of the single dipole, the field intensity at a sky-wave range $2r$ is given by

$$E = MD(\psi)/2r \tag{4}$$

[3] K. A. Norton, "The Calculation of Ground Wave Field Intensity Over a Finitely Conducting Spherical Earth," *F.C.C. Hearing in the Matter of Aural Broadcasting*, Washington, D. C., 1940. Lithographed manuscript.

[4] See footnote reference 3.

[5] "IRPL Radio Propagation Handbook, Part 1," Washington, D. C.: Interservice Radio Propagation Laboratory.

where the value of M has been given in connection with (3) and $D(\psi)$ is plotted in Fig. 3. It is thus necessary to relate r and ψ to the ground range s and the ionosphere height h by means of the geometry indicated in Fig. 6.

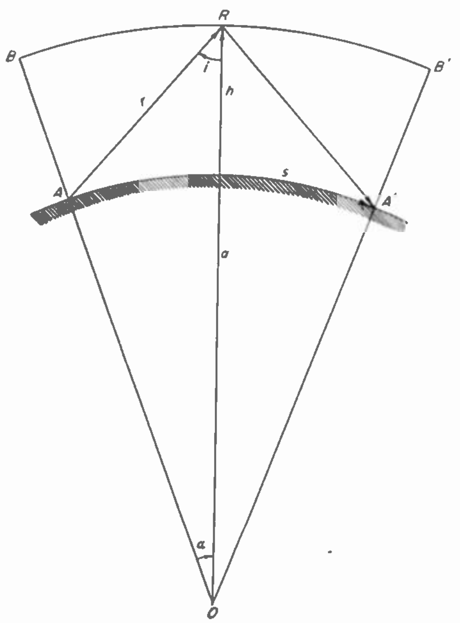

Fig. 6—Diagram representing path of sky wave. BRB', ionosphere; ASA', surface of earth; O, center of earth; A, transmitters; A', receiver; R, reflection point; a, radius of earth; h, height of ionosphere; s, range along earth's surface; α, ½ path angle; r, ½ sky-wave range.

From Fig. 6, it is easily shown that the desired relationships are

$$r = \left[2a(a+h)(1-\cos\alpha) + h^2\right]^{1/2} \tag{5}$$

and

$$\psi = \cos^{-1}\left[(a+h)(\sin\alpha)/r\right] \tag{6}$$

where the notation is indicated in Fig. 6. It should be noted that these relations apply only for the "single-hop" transmissions. For "multihop" paths involving m "hops" it is necessary to divide the ground-wave range by m and determine the "single-hop" field at this distance. The "multihop" field is then determined by dividing this result by m.

By the application of Martyn's theorem,[6] it follows that the relation

$$f_c = f\left[h + a(1-\cos\alpha)\right]/r \tag{7}$$

may be used for calculating the skip distance when the vertical-incidence critical frequency f_c is known and is less than the operating frequency f.

[6] D. F. Martyn, "The propagation of medium radio waves in the ionosphere," *Proc. Phys. Soc.*, vol. 47, pp. 332–339; March, 1935.

VI. E-Layer Sky-Wave Field

It is well known that the E-layer height remains essentially constant. Consequently, assuming a reasonably constant height, the above relations may be used to determine the E-layer sky-wave field as a function of distance.

Utilizing (4), (5), and (6) in conjunction with the 2.398-Mc. "overland" curve of Fig. 3, the sky-wave field as a function of range is obtained. The results appear in Fig. 7. This assumes an E-layer height of 110 km. It is

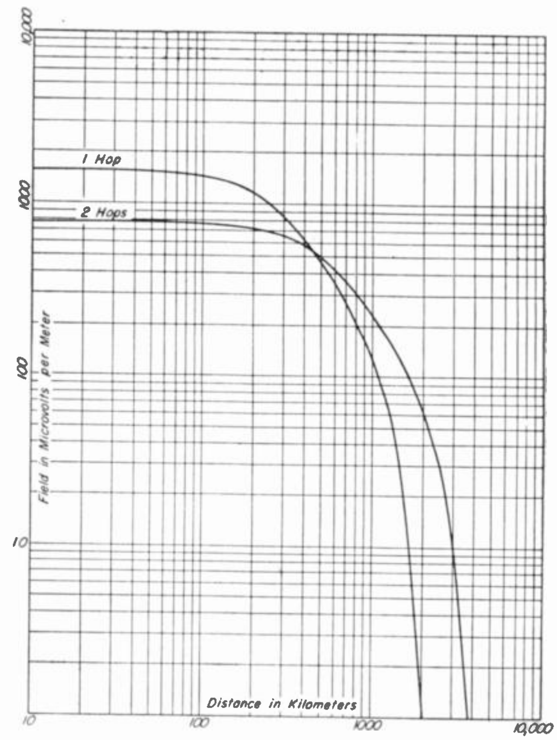

Fig. 7—E-layer sky-wave field at the surface of the earth as a function of range, under same conditions as in Fig. 4. Number of hops as a parameter. Constants assumed are noted in the text.

evident that the "one-hop" E-layer range is approximately 2000 km. and is essentially independent of reasonable transmitter powers. When these curves are compared with the relevant curve of Fig. 4, it is evident that sky-wave transmission is predominate for all ranges of interest with the type of transmitting antenna in question.

VII. F-Layer Sky-Wave Field

In contradistinction to the E layer, the F-layer height varies widely, particularly with the season of the year. During the summer months, also, the F region separates into two distinct layers, F_1 and F_2. As a result of these variations, it is not useful, for present purposes, to attempt to deal in detail with F-layer field strengths. An order-of-magnitude result may, nevertheless, be obtained by assuming an F-layer height of 270 km.

The 6.425-Mc. sky-wave field strength obtained with these assumptions is shown in Fig. 8. It is evident that

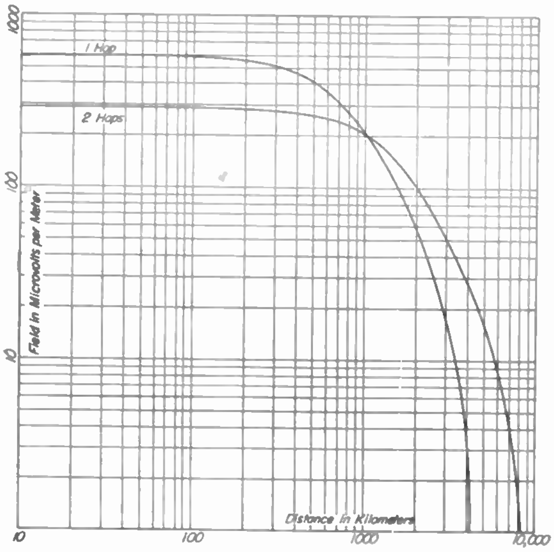

Fig. 8—*F*-layer sky-wave field at the surface of the earth as a function of range under same conditions as in Fig. 4. Number of hops as a parameter. Constants assumed are noted in the text.

the "one-hop" *F*-layer range is approximately 4000 km. and is also essentially independent of reasonable transmitter powers.

VIII. Restriction of Sky-Wave Range By a Vertically Directive Transmitting Antenna

An obvious method of restricting the range of sky-wave transmissions is to use an antenna system which is vertically highly directional, and therefore radiates but little power at the lower angles involved in long-distance transmission. It is essential that no low-angle side lobes occur in the directivity pattern chosen, for the same reason.

Vertical directivity may be obtained by the well-known methods of "stacking" driving antennas above one another at suitable separation of the elements, or by placing driven elements broadside to the direction in which the directivity is required. For present purposes it is necessary to obtain an array directivity which is satisfactory in all vertical planes passing through the center of the array, and at all angles to the array-element axis. Since, in either case, it is necessary to utilize at least four supporting towers, it was deemed advisable to consider only the broadside array, since this involves towers of minimum height.

It can be shown that when two antenna elements, with equal currents, having directivity D, are placed a center spacing distance S apart, the directivity of the array is given by[7]

[7] M.I.T. Radar School, "Principles of Radar," Chap. IX. Cambridge, Mass., 1944.

$$D_2 = 2D \cos\left[(\pi S/\lambda) \cos \psi\right] \tag{8}$$

where λ is the wavelength measured in the same units as S, and ψ is the angle of elevation measured from the horizontal. Attention is confined to the case $S/\lambda = 1/2$. If, further, n combinations of the above double elements are superposed so as to form an array with a binomial current distribution, the following directivity pattern is obtained.

$$D_{n+1} = 2^n D \cos^n (1/2\pi \cos \psi), \tag{9}$$

with the array comprised of $n+1$ elements. The relative current in the rth element is given by the coefficient of the rth term in the binomial expansion

$$_nC_r = \frac{n!}{r!(n-r)!}; \tag{10}$$

hence the name "binomial array" for this type of antenna structure.

From (9) it is evident that the array directivity is linearly related to the element directivity. The single dipole antenna, whose directivity in the equatorial plane is shown in Fig. 3, was therefore chosen as the elementary antenna. Since the element antenna has no side lobes, the array using this element will also have a directivity pattern without side lobes. As indicated by (1) and (3), the directivity of the element antenna in the axis of the antenna is obtained by multiplying the equatorial directivity by $\sin \psi$. The directivity at intermediate azimuth angles is given by multiplying the equatorial directivity by $[1-\sin^2 \xi \cos^2 \psi]^{1/2}$. Thus the equatorial and antenna axis directivities are limiting cases, and their determination is sufficient in establishing the limiting directivities in the three-dimensional pattern.

IX. Restricted-Range *E*-Layer Sky-Wave Field

To determine the feasibility of restricting the range of the *E*-layer reflected sky-wave field, it is convenient to specify some distance, much less than the normal one-hop distance, at which the sky-wave field will have a specified value approaching the limiting value which can be received through receiver and atmospheric noise. It is deemed sufficient to specify a no-absorption "one-hop" range of 500 km. for a 1-microvolt-per-meter sky-wave field, at the ground, as a basis for a feasibility check.

Utilizing (4) for determining the required directivity in conjunction with (2) and (9) determines the number of elements required to obtain this directivity. When this is done for 2.398-Mc. transmissions, with an assumed *E*-layer height of 110 km., it is found that a 4×4 horizontal mattress satisfies the directivity requirements. This is comprised of four ranks of four-element collinear arrays with 1/2-wavelength separation between the ranks. Utilizing (10) indicates that a 1–3–3–1 current distribution is required in each rank, and a 1–3–3–1 distribution between ranks, so that the maximum current ratio between elements is 9 to 1. This, in conjunction with the element dimensions at this frequency, results in a practical antenna configuration.

The resulting directivity pattern for the array described above has been calculated and appears in Fig. 9.

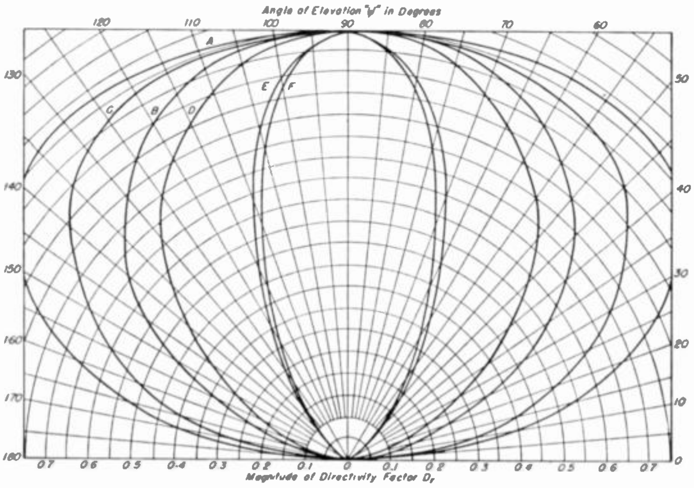

Fig. 9—Relative voltage directivity, normalized to 1.00 in the vertical, of three antenna systems in each of two principal planes. See Fig. 10 for schedule.

As a basis for comparison, the relevant portion of the curve of Fig. 3 for the array element is also plotted. In addition, the calculated curves for the element over a ground mat is shown. This indicates that a considerable increase in vertical directivity is obtained by the use of a ground mat at these frequencies.

Utilizing Fig. 9, the "one-hop" E-layer sky-wave field as a function of range has been calculated, and appears in Fig. 10. As will be noted, a 4-to-1 restriction in range is feasible.

Two factors of practical importance do not appear on the curves. The first is the great reduction in transmitter power that may be obtained by utilizing the array. As an example, it is easily shown that the same vertical-incidence sky-wave field is obtained using the array radiating 150 watts as is obtained with a single dipole radiating 1 kw. Since the curves of Fig. 10 are normalized to unity in the vertical, it is evident from this figure that the sky-wave fields of the two antenna systems, using the above power ratio, are within 8 db of each other out to 100 km. Beyond this distance range the array field drops off rapidly, as desired.

Another factor of practical importance is the effect of the reduction of the vertical-incidence critical frequency of the E layer, during night hours. From (7) there may be obtained the relevant curves which appear in Fig. 11. On this figure, areas to the left and below a given curve correspond to regions where E-layer sky-wave signals are not received. Thus, as the vertical-incidence critical frequency becomes less than the

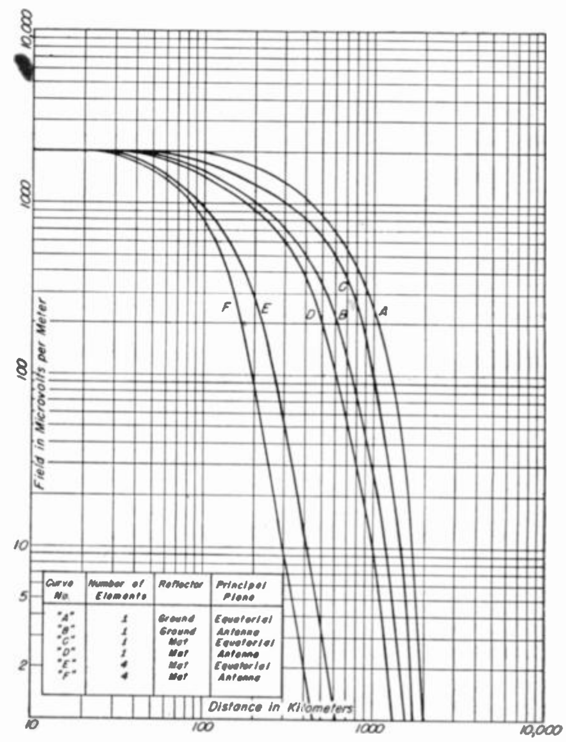

Fig. 10—"One-hop" E-layer sky-wave field at the surface of the earth as a function of range for the three antenna systems of Fig. 9. Curves A and B under same conditions as in Fig. 7. Other curves normalized to same value in the vertical.

operating frequency, the skip distance increases and, for the present example, becomes 500 km at a vertical-incidence critical frequency of 1 Mc.

To consider the effect of this factor, we shall use two examples. For an observer at 50 km., normal reception

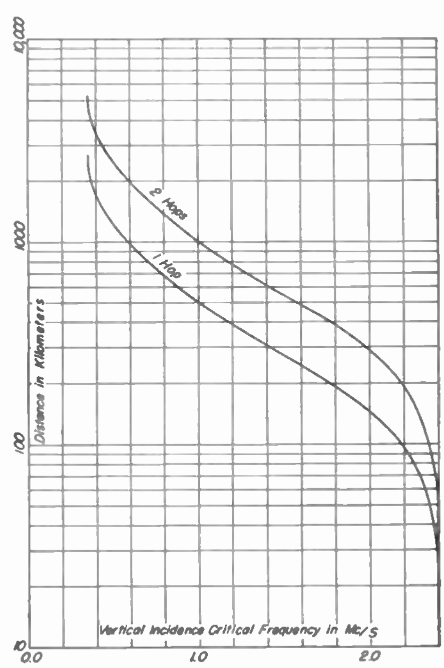

Fig. 11—"Skip distance" within which the regular E-layer sky-wave field does not appear as a function of vertical-incidence critical frequency.

will occur until the vertical-incidence critical frequency decreases to 2.37 Mc. For this frequency, and lower, E-layer transmission cannot occur. However, F-layer transmission can, and will, occur; so that, neglecting absorption, and change in path length, the observer will note no change in signal unless F penetration occurs, which is very unlikely. For an observer at 500 km., similar statements apply, except that the change in the mode of transmission occurs at 1 Mc. As will be shown in the next section, the restriction of the F-layer range requires a much narrower beam than the E-layer case. Consequently, if the vertical-incidence critical frequency becomes less than 1 Mc., the restriction of the sky-wave range to 500 km. is not possible by this means.

In view of the above, and for the given example, the use of this array will successfully restrict the E-layer sky-wave range by about a factor of four and will result in a sky-wave field of certain value inside the restricted range with about 1/6 the transmitter power, all with reference to a single horizontal dipole.

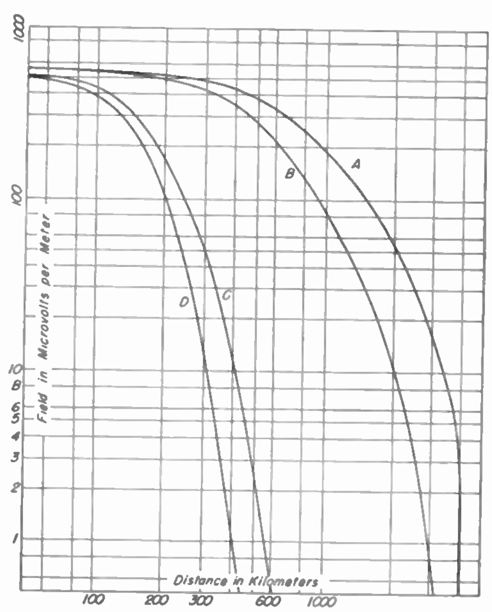

Fig. 12—"One-hop" F-layer sky-wave field at the surface of the earth as a function of range. Curves A and B, same conditions as in Fig. 8 in equatorial and antenna planes, respectively. Curves C and D, using the array described in the text, in element equatorial and antenna planes, respectively, normalized to same value on vertical as curves A and B.

X. Restricted-Range F-Layer Sky-Wave Field

F-layer transmission may be treated in exactly the same way as E layer, taking into account the greater height of the former. Assuming an F-layer height of 270 km., and specifying a 1-microvolt-per-meter "single-hop" sky-wave field at 500 km. for the maximum range, results in a rather complex array requirement. The required array consists of eleven ranks of seven-element collinear arrays with 1/2-wavelength separation between the ranks. A prohibitive practical requirement is that the maximum current ratio between elements is 5040 to 1.

The "one-hop" F-layer sky-wave field as a function of range to be expected with the above antenna appears in Fig. 12. However, due to the complex antenna structure required, this array does not warrant further consideration.

XI. Conclusion

From the results of Section IX, it appears that the sky-wave range of signals normally reflected from the E layer may be reduced by about a factor of four by utilizing a feasible vertically directive transmitting antenna system. Further, a given field intensity within the restricted range may be obtained with much less transmitter power when this antenna is used, as compared with more commonly encountered types. Finally, range restriction may be obtained even under the condition that the operating frequency is above the vertical-incidence E-layer critical frequency, as long as the E-layer maximum usable frequency (m.u.f.) for the stipulated range is greater than the operating frequency.

Before the proposed scheme can be reduced to practice, the effect of absorption in the ionosphere must be determined; preferably on a theoretical basis. An approach to this problem has been devised and will be reported by one of the writers elsewhere. It is thought that this effect can be countered by changing the power of the transmitter, without affecting the range restriction, as the absorption varies throughout the day.

In view of the approximations made in this paper, the conclusions require experimental verification. Experiments are underway to obtain this verification.

Recent Developments in Frequency Stabilization of Microwave Oscillators*

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Summary—**A system developed by R. V. Pound for frequency-stabilizing a microwave oscillator is discussed. The frequency range of the Pound stabilizer is considered, and a change in the microwave circuit is described which increases the usable frequency range of the stabilizing circuit. This new circuit is discussed in detail, and a graphical method of obtaining the frequency versus voltage characteristic is presented. The effect of harmonic distortion in the output of the stabilizing circuit when the microwave oscillator is frequency-modulated is discussed, and the amount of the distortion is evaluated.**

Introduction

It is the purpose of this paper to present some recent developments in the field of microwave frequency stabilization. Work has centered on a stabilization system[1] developed by R. V. Pound, and in particular on the microwave frequency discriminator which it incorporates. Emphasis has been placed not on improving the already high stability of this system but on developing the stabilizer into an engineered system, free of involved tune-up procedure and dependence on the uncontrolled characteristics of microwave tubes and crystals.

I. The Pound Stabilizer

A block diagram of the original Pound system is given in Fig. 1. Also indicated in this figure is a convenient way of plotting the detected discriminator output voltage as a function of frequency on an oscilloscope. Power from the microwave oscillator divides at the magic tee between the two adjacent arms. The useful energy component reflected from the reference-frequency cavity goes to the modulating crystal, which reflects the "carrier-frequency" energy incident on it in the form of two sidebands at carrier frequency plus and minus the modulating frequency, suppressing the carrier. These sidebands, combining at the detector crystal with the carrier-frequency signal entering directly from the source arm of the magic tee, give rise to a modulation-frequency signal at the detector-crystal output. It is convenient to consider the detector-crystal output signal as having a magnitude which is a function of the imaginary component of the reference-cavity reflection coefficient, and a phase which shifts by 180° as the frequency of the microwave source goes through the resonant frequency of the reference cavity. After amplification in the modulation-frequency (30-Mc.) amplifier,

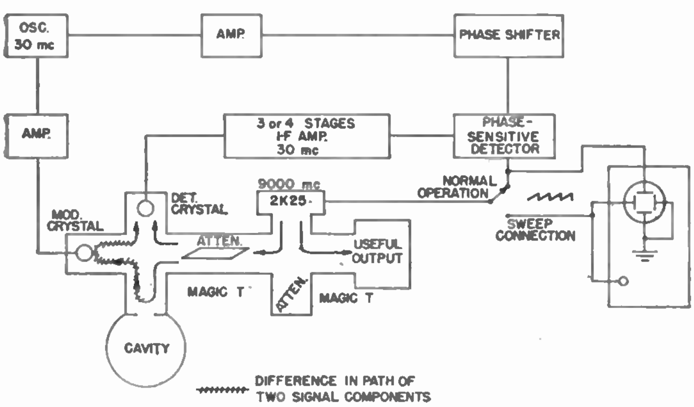

Fig. 1—Block diagram of the Pound stabilizer.

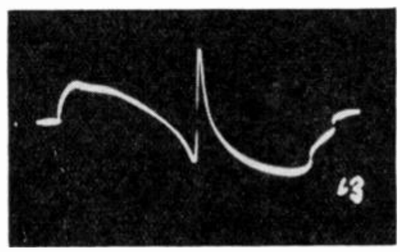

Fig. 2—Typical discriminator curve for the Pound system, no crystal bias.

the discriminator output is compared in phase with the signal applied to the modulating crystal. The phase-sensitive detector employed for this purpose produces a voltage output which, it has been shown, for a matched cavity, closely approximates the following relation:

$$E = \frac{\Delta}{1 + \Delta^2} \quad (1)$$

where

$\Delta = Q\, df/F$
Q = unloaded Q of cavity
F = resonant frequency of cavity
df = deviation from frequency F.

Deviations from the theoretical waveform make Fig. 2 typical of the discriminator curves obtained with the Pound circuit. Fig. 2 is a photograph of an oscillogram produced with the circuit of Fig. 1 by sweeping the fre-

* Decimal classification: R355.912. Original manuscript received by the Institute, December 15, 1947. This work has been supported in part by the Signal Corps, the Air Matériel Command, and the Office of Naval Research.

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[1] R. V. Pound, "Frequency stabilization of microwave oscillators," Proc. I.R.E., vol. 35, pp. 1405–1415; December, 1947.

quency of a 9000-Mc. oscillator over a 60-Mc. frequency range (cavity $Q=9000$). These deviations are undesirable if, when the stabilizer is switched on, it is to lock the oscillator on the correct frequency without further attention. Their major cause is mismatch of the detector crystal at the edges of the oscillation mode of the klystron, where there is low power output and hence low crystal current. A d.c. bias of 0.25 volt across the crystal in such a direction as to increase crystal current will stabilize crystal impedance, and will permit the improved curve of Fig. 3 to be realized.

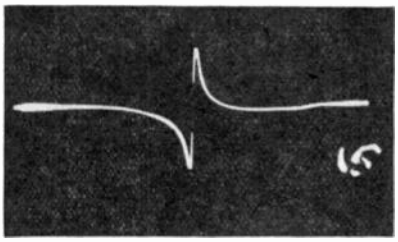

Fig. 3—Typical discriminator curve for the Pound system, biased crystal.

Pound's system, while representing a marked advancement in stabilizing technique, has an inherent limitation in that critical phase relations within the waveguide discriminator depend on the difference in electrical length between two waveguide paths of considerably different physical length. The effect of this path-length difference may be resolved into three separate phase shifts, two of which are functions of the microwave frequency. The most important of the factors will be evaluated first.

A carrier-frequency component of guide wavelength l will have a new guide wavelength, $l \pm dl$, when the frequency is changed. After traversing n wavelengths the total apparent phase shift in this component will be ndl. In terms of more tangible factors, if F is the microwave frequency in cycles per second, dF is the total change in F, L is the length of the difference path in centimeters, c is the velocity of light, and f_c is the cutoff frequency for the waveguide used, then the phase shift of the carrier in degrees ϕ_1, caused by a frequency change dF, is

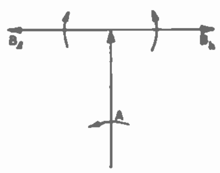

Fig. 4—Relation of vectors entering waveguide.

$$\phi_1 = \frac{360FdFL}{c\sqrt{F^2 - f_c^2}}, \quad (2)$$

or, for $1 \times \frac{1}{2}$-inch waveguide (0.050-inch wall) at 9000 Mc., ϕ_1 is 0.0175° cm./Mc.

Stated in other terms, the theoretical maximum range of frequencies over which the Pound circuit can operate, even with the waveguide arm lengths reduced to 4 cm. each, is less than 640 Mc. at 9000 Mc. (Note from Fig. 1 that the total path length differential is 16 cm. in this case.)

The two other phase shifts, which are of negligible importance in any practical discriminator of this type, can be evaluated by considering the waveguide section through which sidebands must travel. The phase shift between the sidebands in this section, ϕ_2, also determines whether the signal at the detector crystal is a phase- or amplitude-modulated wave, and is a function of the modulating frequency.

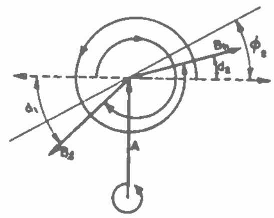

Fig. 5—Exaggerated vector relations after one guide wavelength.

The rotating-vector representation of a pair of sidebands, B_h and B_l, and a carrier A is shown in Fig. 4. Assume that, as shown in Fig. 4, the phase relations are proper for amplitude-modulation sidebands when the wave enters a short section of waveguide. In traversing one wavelength of the guide (for the carrier) the sidebands will be shifted in phase relative to the carrier, and an exaggerated vector diagram will appear as in Fig. 5. Note that the lower sideband B_l has shifted through a smaller angle than the carrier, while the upper sideband B_h has shifted through a larger angle than the carrier. Also note that the angles d_1 and d_2 are not exactly the same because the wavelength in the guide changes more rapidly as the cutoff frequency is approached. The angle ϕ_2 then represents the amount by which the phase relation of carrier to sidebands has varied in one wavelength of guide. The angle ϕ_2 can be evaluated as

$$\phi_2 = \left[\sqrt{f_h^2 - f_c^2} - \sqrt{f_l^2 - f_c^2}\right] \times \frac{180 \times L}{c}. \quad (3)$$

For a modulating frequency of 30 Mc., a center frequency of 9000 Mc., and with $1 \times \frac{1}{2}$-inch waveguide,

$f_h = 9030 \times 10^6$ c.p.s.
$f_l = 8970 \times 10^6$ c.p.s.
$f_c = 6561.7 \times 10^6$ c.p.s. = guide cutoff frequency
$c = 2.998 \times 10^{10}$ cm./sec.
$\phi_2 = 0.526$ degree per cm. of waveguide.

An error of this type may be introduced by variations of the modulating frequency. For constant modulation frequency, the total phase shift may be adjusted to the proper value by adjustment of the cavity arm length.

A third phase error ϕ_3 is found from the derivative of ϕ_2 with respect to the microwave frequency, which is given by

$$\frac{d\phi_2}{df} = \left[\frac{f_l}{\sqrt{f_l^2 - f_c^2}} - \frac{f_h}{\sqrt{f_h^2 - f_c^2}}\right] \times \frac{180 \times L}{c}. \quad (4)$$

With a 30-Mc. modulating frequency, $f_c = 6561.7 \times 10^6$, and the carrier frequency $= 9000 \times 10^6$, $\phi_3 = 0.0666°$ cm./1000 Mc. This ϕ_3 is so small as to be completely negligible in any discriminator circuit investigated.

II. The Equal-Arm Discriminator

The equal-arm discriminator shown in the block diagram of Fig. 6 was first used by one of the authors in January, 1946. It was not until this research was well along that it was discovered that there were beneficial

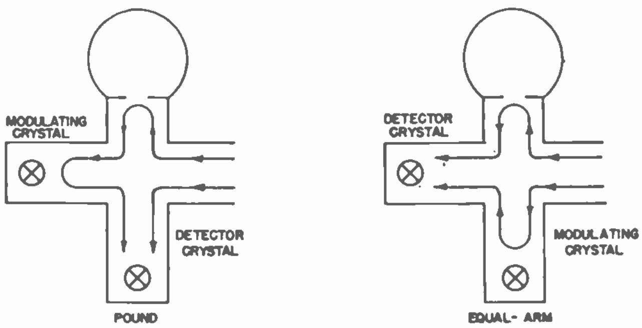

Fig. 6—Comparison of discriminator circuits.

effects achieved in addition to the broadbanding of the device by the equalization of the internal signal paths.

The physical similarity of the equal-arm discriminator to the Pound discriminator is deceiving. The only external indication of a change is that the modulating crystal and detector crystal positions have been interchanged. There are, however, six fundamental differences in operation which bore investigation, and will be discussed in sequence. These are:

(1) The frequency range has been extended because of path equalization.

(2) Reflections which can cause spurious signals are eliminated.

(3) Sideband energy is transmitted to the detector crystal with greater efficiency, giving increased over-all discriminator sensitivity with the same input power.

(4) Power input may be several db greater for the same detector-crystal noise.

(5) Large signals at twice the intermediate frequency are generated when the microwave source frequency is near the resonant frequency of the cavity.

(6) The carrier energy, rather than the sideband energy, is a function of frequency; thus the detector output varies as a function of the carrier-to-sideband ratio.

A. Increased Frequency Range

By reference to Fig. 6, it may be noted that, in the equal-arm discriminator, the waveguide path via the modulating crystal (which produces the sideband energy) can be made equal to the path of the carrier energy reflected from the cavity. This means that the relative phases of the two energy paths may be made constant over wide frequency ranges, and thus that the discriminator is no longer limited to the narrow band of operation of a single-control Pound system. In the experimental work it was found possible to make a fixed-tuned discriminator whose range was greater than that of the available microwave source (1100 Mc. in 9000). By comparison, a fixed-tuned (i.e., fixed waveguide lengths) Pound discriminator, with all path lengths minimized, covered less than a 500-Mc. range, 350 being a typical value.

At 9000 Mc. the minimum path-length difference obtainable in the Pound arrangement is about 16 cm., which allows 4 cm. for the modulating crystal termination and a similar length for the cavity arm.

These measurements, in the case of a TE_{011}-mode cavity, are made between the center post of the magic tee and the cavity side of the coupling iris. The effective modulator-crystal arm length has not been measured under operating conditions. A few d.c. measurements indicate that the length should be measured from the center post to some point between the crystal and the end plate, but their validity under operating conditions is questionable.

The theoretical frequency-range calculations check to within 20 per cent of measured values when the path-length difference is increased to 60 cm. Since they do not check as well for small path-length differences, one is inclined to suspect fringing effects at the magic-tee junction, as well as an uncertainty in the exact location of the effective position of the modulating crystal.

B. Elimination of Reflections

In the new circuit the power reflected from the modulating crystal divides between two matched loads, the detector crystal, and the source arm. This is in distinct contrast to the Pound arrangement, where the sideband power divides between the detector crystal and cavity. The cavity is far from being matched at the sideband frequencies, and in Pound's system will reflect energy back into the modulating crystal for remodulation. The equal-arm system will reflect more sideband energy into the attenuator in the source arm than the Pound system, but if the source is connected into the discriminator through a magic tee, the sideband energy getting into the useful output will be at least 43 db below the carrier level.

C. Increased Sensitivity

A very important feature of the new configuration is indicated by comparing the modulation-frequency output with that of its predecessor. The same power input to each discriminator is assumed, of course.

The sideband energy suffers the same modulator-crystal loss in each case, but in the equal-arm circuit traverses the magic tee one time less and does not encounter the 6-db loss at the cavity. This is a total increase of 9 db over the Pound circuit. As will be seen, however, only about a 5-db improvement can be realized because of the influence of the carrier-to-sideband ratio.

D. Increased Power-Handling Capacity

In the new discriminator the power reaching the detector crystal via the modulating crystal loses 6 db from two traverses of the magic tee, and 3 to 10 additional db are lost in the modulating crystal, depending on the efficiency of sideband production. The total loss is, therefore, 9 to 16 db. If the cavity is well matched, the detector-crystal current caused by the power reflected from the cavity in the vicinity of resonance is very small. By comparing this result with the total of 3 db loss in the Pound circuit (between source and detector crystal), it may be seen that an input increase of 6 to 13 db is possible before the same crystal current (and, therefore, noise) is produced in the equal-arm unit. Thus, if the microwave source can supply the power, even greater discriminator output than the 5-db increase previously mentioned can be realized. It must be remembered, of course, that the isolation between source and cavity must be great enough to prevent the reference cavity from "pulling" the oscillator.

E. Variable Carrier Amplitude

Considerable importance should be attached to the fact that it is the carrier rather than the sideband energy which is attenuated as the cavity of the equal-arm discriminator is varied through resonance. With normal modulating-crystal efficiencies, the carrier-frequency energy arriving at the detector crystal is usually of smaller amplitude than the sideband energy. This is analogous to overmodulation at the detector crystal.

Two effects of this overmodulation are important: the production of large double-frequency components of the modulation frequency when source and cavity frequency are nearly identical, and, more important, a decrease in the effectiveness of the sideband energy in producing output at the intermediate frequency. The double-frequency signal is of small concern, unless it overloads the first tube of the modulation-frequency amplifier. In this case, it may be reduced easily by a filter network in the input to the amplifier. The second effect, however, produces a very definite change in the crystal output voltage as a function of the carrier-to-sideband ratio. The discriminator characteristic is, therefore, modified somewhat.

A Fourier analysis may be performed on the envelope of the signal impressed on the detector crystal to find the useful signal component. The result of such an analysis gives

$$\frac{a_1}{2B} = \frac{2}{\pi}\left[\frac{A}{2B}\sqrt{1-\left(\frac{A}{2B}\right)^2} + \sin^{-1}\left(\frac{A}{2B}\right)\right] \qquad (5)$$

where B is the sideband voltage, A is the carrier voltage, and a_1 is the crystal output voltage at modulation frequency. The quantity $a_1/2B$ is plotted in Fig. 7 as a function of $A/2B$, the carrier-to-total-sideband voltage ratio.

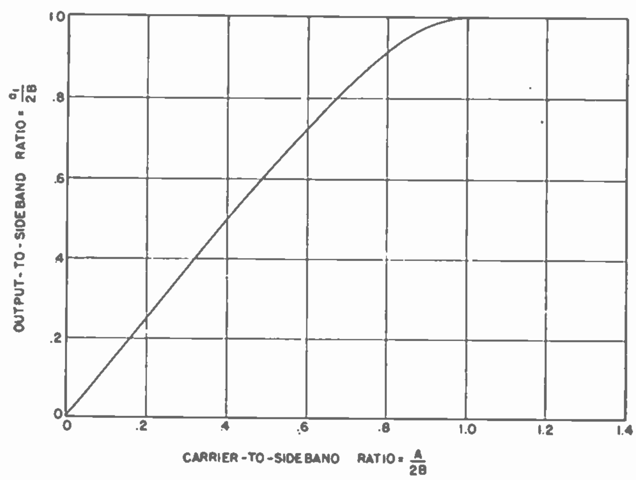

Fig. 7—Result of Fourier analysis.

F. Calculation of Discriminator Characteristics

It has been found convenient to use a graphical method to calculate the characteristics of the equal-arm discriminator. The multiple graph shown in Fig. 8 allows rapid plotting of the discriminator curve for any modulating crystal efficiency.

At any desired value of Δ (the normalized frequency scale of Fig. 8(a)), the value of A (the useful part of the cavity reflection coefficient), can be read from the dashed thin-line curve. Fig. 8(b) is a set of curves correcting for the fact that the ratio of carrier-to-sideband voltage $A/2B$ depends on both the carrier-frequency component reflected by the cavity and the efficiency with which first-order sideband energy is generated. By entering the value of A obtained from Fig. 8(a) on the proper efficiency curve in Fig. 8(b), it is possible to read off the value of $A/2B$ which has resulted from the value of frequency error Δ chosen initially. To find $a_1/2B$, the efficiency with which a lossless detector crystal converts the modulated signal impressed on it to an output signal at modulation frequency, the value of $A/2B$ found from Fig. 8(b) is transferred to Fig. 8(c). Having determined $a_1/2B$, it is only necessary to multiply by $2B$ to get the output a_1. The straight lines graphed in Fig. 8(d) determine the value of a_1 for any modulating crystal efficiency and ratio $a_1/2B$. To permit the value of a_1 to be transferred easily to Fig. 8(a), where it is plotted against the value of Δ to give the desired discriminator curve, a one-to-one transfer curve (shown as a double-dashed line) has been located on Fig. 8(a).

The value of a_1 is found graphically for a crystal efficiency of 12.5 per cent at the point where Δ equals 0.5 in Fig. 8 to show the graphical construction involved. For this case, a_1 is 0.457. Choosing several other values of Δ allows the entire curve for a modulating-crystal efficiency of 12.5 per cent to be drawn. Other curves for different efficiencies may be drawn in a similar manner.

The slopes of the lines in Fig. 8(b) were obtained by the following reasoning:

The maximum value to which the ratio $A/2B$ can rise is determined by the efficiency of the modulating crystal. The quantity A is limited by the reflection coefficient of the cavity and two traverses through the magic tee (see Fig. 6) to the value

$$A = V_{\text{input}} \times 0.707 \times 0.5 \times 0.707 \qquad (6)$$

where V_{input} is the voltage into the discriminator.

Similarly, the value of $2B$ is limited by the input voltage, the modulating crystal efficiency (*Eff*), and two traverses of the magic tee. Note that the voltage of each sideband reflected from the crystal bears the following relation to the efficiency (which is defined on a power basis as P_r/P_i):

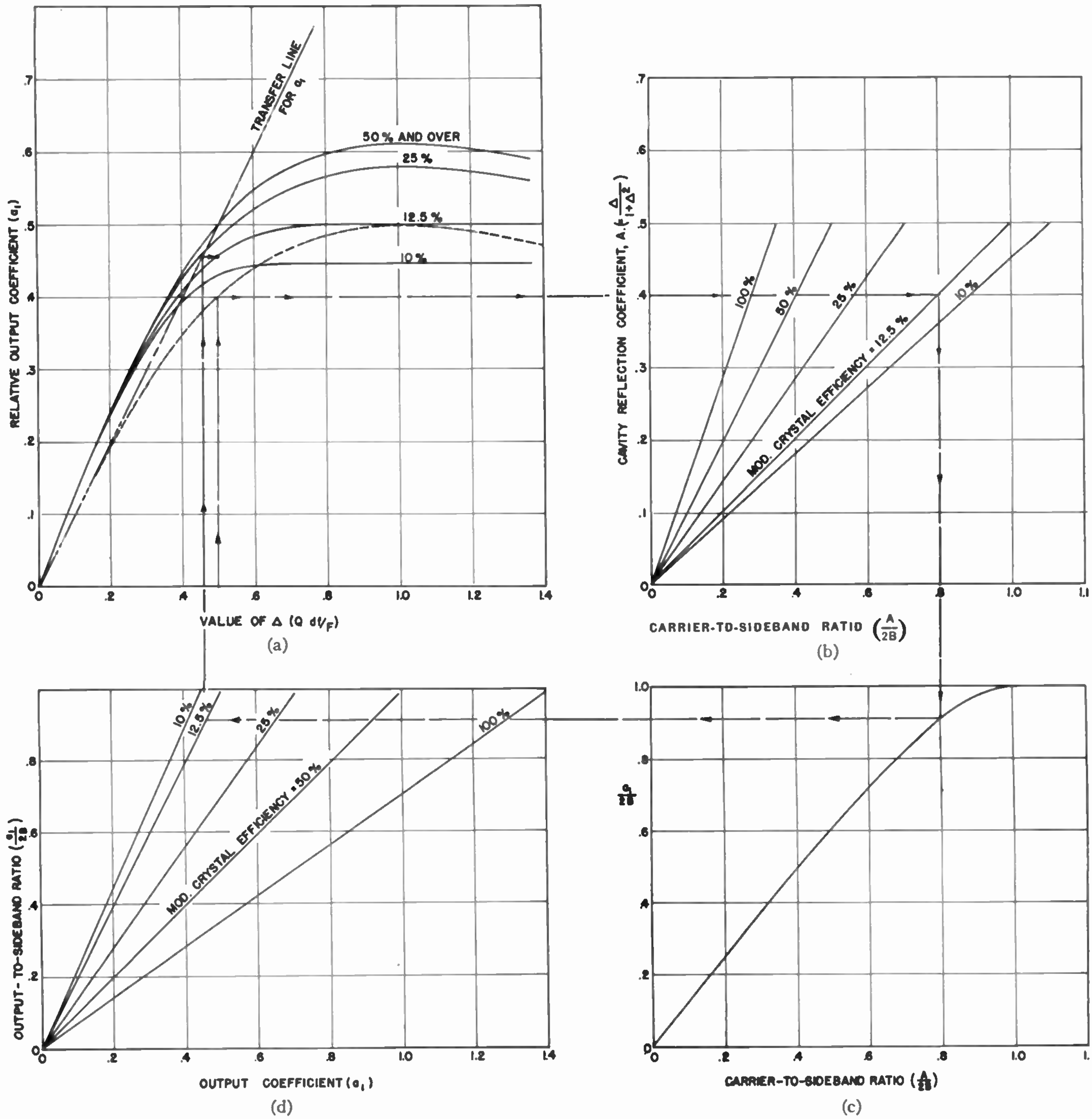

Fig. 8—Graphical calculation of discriminator waveforms.

$$\frac{\text{Reflected Voltage of Each Sideband}}{\text{Incident Voltage}} = \sqrt{\frac{P_r/2}{P_i}} = \sqrt{\frac{Eff}{2}} \quad (7)$$

where $P_r/2$ is the power in each of the two first-order sidebands reflected from the crystal, and P_i is the total carrier-frequency power incident on the crystal.

Accounting for the losses in the sideband path, therefore,

$$B = V_{\text{input}} \times 0.707 \times 0.707\sqrt{Eff} \times 0.707, \quad (8)$$

and the ratio

$$\left(\frac{A}{2B}\right)_{\max} = \frac{0.3535}{\sqrt{Eff}}. \quad (9)$$

Since in Fig. 8(a) the maximum value of A has been chosen as 0.5, the slopes of the efficiency lines in Fig. 8(b) are found from

$$\frac{A}{\left(\frac{A}{2B}\right)_{\max}} = \frac{0.5}{0.3535/\sqrt{Eff}} = \sqrt{2} \times \sqrt{Eff}. \quad (10)$$

The slopes of the efficiency lines in Fig. 8(d) are chosen so as to multiply the $a_1/2B$ scale of Fig. 8(c) by the proper value of $2B$. From (6) and the fact that $A_{\max}$ has been defined as 0.5, V_{input} is equal to two. Using this result in (8),

$$2B = \sqrt{2} \times \sqrt{Eff}, \quad (11)$$

which could have been obtained directly from (10). Therefore, the slopes of the lines in Fig. 8(d) are

$$\frac{\left(\frac{a_1}{2B}\right)}{a_1} = \frac{1}{2B} = \frac{0.707}{\sqrt{Eff}}. \quad (12)$$

III. Distortion

It has been mentioned earlier that the output of the phase-sensitive detector in Pound's system closely approximates the expression

$$E = \frac{\Delta}{1 + \Delta^2}. \quad (13)$$

As a matter of fact, this expression is exact for high-efficiency crystals and operation between the peaks of the demodulator curve. This equation has been subjected to harmonic analysis to determine the harmonics present in the output of the phase-sensitive detector when the oscillator frequency is sinusoidally modulated. The result of this analysis is shown in Fig. 9, a plot of the harmonic distortion (in db below fundamental) as a function of the normalized frequency deviation (normalized with respect to the frequency deviation giving maximum peak-to-peak output). As is shown in this figure, distortion at low deviations is low enough to permit operation of multichannel frequency-division multiplex systems without appreciable crosstalk from nonlinearity. At high deviations, distortion is slightly greater than that present in the Foster-Seeley discriminator, but is still reasonably low for single-channel operation. If the

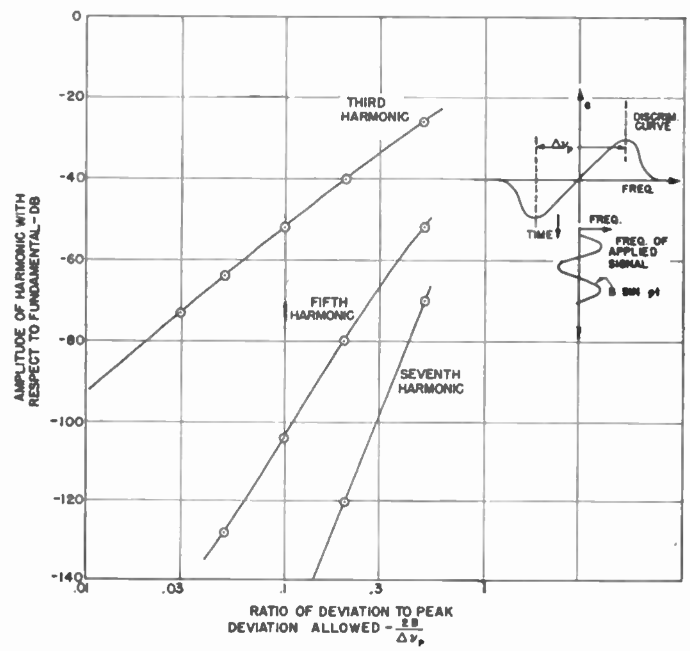

Fig. 9—Harmonic distortion in the balanced discriminator.

bandwidth of the feedback loop comprising the stabilizing system is wide enough to pass all components of the modulating wave, modulation may be applied in series with the output of the phase-sensitive detector. The stabilizer system will act to reduce the frequency modulation caused by the modulating wave, thus giving negative feedback. In the limit, the linearity of such a modulation system is the same as that of the microwave discriminator, and the distortion will be as shown in Fig. 9. It is interesting to note that the frequency versus modulating-voltage characteristic obtained in this manner is identical to the voltage versus frequency characteristic of the cathode-driven discriminator,[2] and hence a transmission system using a modulated stabilized microwave oscillator and a properly matched cathode-driven discriminator may be made highly linear, independent of the characteristics of the microwave transmitter tube employed.

IV. Conclusions

The equal-arm discriminator described above is a microwave discriminator with no spurious locking frequencies anywhere in a 12 per cent band. When this circuit is used with an oscillator tube such as the 2K25, tune-up procedure is reduced to two adjustments: the reference cavity is set to the desired operating frequency, and the

[2] W. G. Tuller and T. P. Cheatham, Jr., "Adjustable-bandwidth f.m. discriminator," *Electronics*, vol. 20, pp. 117–119; September, 1947.

oscillator-tube cavity is tuned for maximum output. This procedure holds anywhere within the tuning range of the 2K25. If a thermally tuned tube is used, even the oscillator-cavity tuning adjustment may be dispensed with. The circuit has the capability of being frequency-modulated with inherent negative feedback and low distortion. It has proved very reliable in use in laboratory microwave power sources for the past eighteen months, giving sure lock-in of oscillator frequency reliably from a cold start each time it was turned on.

Pseudosynchronization in Amplitude-Stabilized Oscillators*

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***Summary*—The effect of external signals on an amplitude-stabilized oscillator is discussed, and it is shown (a) that "pulling effect" is usually nonexistent, and (b) that an apparent synchronizing effect observable experimentally is due to a totally different phenomenon. Differences between these results and those given by Adler for different conditions are pointed out and explained.**

Amplitude stabilization of oscillators by one of the two methods of Fig. 1[1] has been used not only to obtain low harmonic content and constant amplitude, but also to achieve superior frequency stability. An important characteristic relating to frequency stability in oscillators, particularly those used in beat-frequency oscillators, interpolation oscillators, and heterodyne frequency meters, is the degree to which the presence of external signals results in "pulling" or synchronization of the oscillator frequency. The purpose of this paper is to supplement other discussions[2] of locking phenomena with a treatment of the effect of external signals on amplitude-stabilized oscillators.

Amplitude-stabilized oscillators differ from other categories of oscillators in that (1) the tube or tubes operate on a substantially linear portion of their characteristic, and (2) the time constants in the amplitude stabilizing circuit are long, commonly of the order of 0.1 second. The latter property serves to differentiate such oscillators from those for which locking phenomena have been discussed by Adler.[2]

Amplitude-stabilized oscillators of the type represented by Fig. 1(a) will be considered first. The following symbols are used:

e = peak voltage output, equal to the maximum instantaneous sum in the output of the normal oscillator signal of frequency ω_0, and any possible external signal of frequency ω_s. It is the value e to which the stabilizing arrangement responds, providing its time constant is long relative to the period of a beat between ω_0 and ω_s

e_0 = voltage of frequency ω_0 developed by the oscillator in the absence of an external signal

e_0' = voltage developed by the oscillator in the presence of an external signal

e_s = external-signal amplitude in output in the absence of feedback

β = complex feedback factor, a function of both frequency and voltage e (by reason of the stabilizing system).

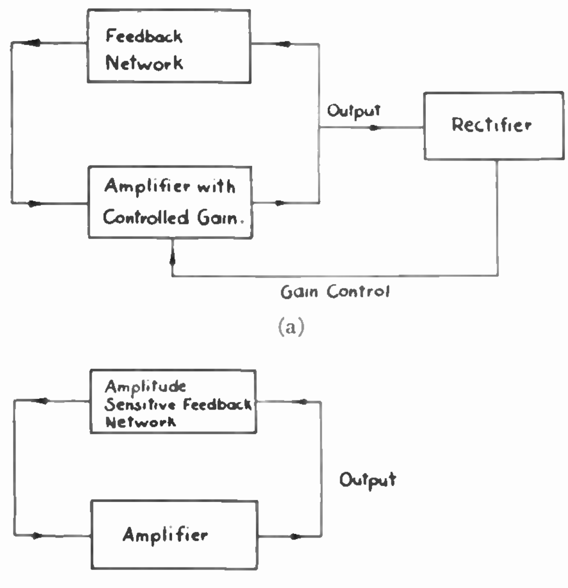

Fig. 1—Block diagrams of the two basic types of amplitude-stabilized oscillator. (a) The automatic-volume-control type, and (b) the nonlinear bridge-stabilized type.

If an external signal, of frequency ω_s, is inserted at any point in an amplitude-stabilized oscillator, it is evident that the output will contain an ω_s frequency component. Any other component of frequency ω in the output, not originating from external injection, must be one for which

$$\beta = 1 + j0$$

at this value of ω and the resulting voltage e. If e and ω

* Decimal classification: R355.917. Original manuscript received by the Institute, June 9, 1947.

† Carnegie Institute of Technology, Pittsburgh, Pa.

[1] P. R. Aigrain and E. M. Williams, "Theory of amplitude-stabilized oscillators," Proc. I.R.E., vol. 36, p. 16–19; January, 1948.

[2] Robert Adler, "A study of locking phenomena in oscillators," Proc. I.R.E., vol. 34, pp. 351–357; June, 1946.

differ by small amounts from e_0 and ω_0, we may write:

$$\beta = 1 + j0 + \frac{\partial \beta}{\partial e}(e - e_0) + \frac{\partial \beta}{\partial \omega}(\omega - \omega_0) \qquad (1)$$

in which $\partial\beta/\partial e$ and $\partial\beta/\partial\omega$ are complex, or of the form

$$\frac{\partial \beta}{\partial e} = a + jb$$

$$\frac{\partial \beta}{\partial \omega} = c + jd.$$

In general, it would be expected that

$$ad - bc \neq 0,$$

which is the condition that $\beta = 1 + j0$ has only one solution; namely,

$$\begin{aligned} e &= e_0 \\ \omega &= \omega_0. \end{aligned} \qquad (2)$$

Thus it follows that the oscillation frequency is unaffected by the external signal; i.e., no "pulling" effect is present. This conclusion agrees with the general findings of van der Pol,[3] who shows that "pulling" effect cannot exist in a system which is completely linear. A phenomenon analogous to nonlinearity could arise in an amplitude-stabilized oscillator when the period of the beat between ω_s and ω_0 becomes longer than the stabilizing time constant so that the system behavior is described by a linear equation with slowly varying coefficients. The beat period T is

$$T = \frac{2\pi}{\omega_s - \omega_0}.$$

It will now be shown that, if $\omega_s - \omega_0$ becomes very small, so that "pulling" might be expected to occur, a new phenomenon arises causing oscillation to cease and ω_0 to vanish. The equation for the peak amplitude e, which, from (2), must be equal to e_0, is

$$e = e_0' + \frac{e_s}{\left|\frac{\partial \beta}{\partial \omega}\right| \left|\omega_s - \omega_0\right|} = e_0$$

in which

$$\frac{e_s}{\left|\frac{\partial \beta}{\partial \omega}\right| \left|\omega_s - \omega_0\right|}$$

gives the injected signal amplitude e_s after amplification by feedback. If

$$\frac{e_s}{\left|\frac{\partial \beta}{\partial \omega}\right| \left|\omega_s - \omega_0\right|} < e_0,$$

which is equivalent to

$$\left|\omega_s - \omega_0\right| > \frac{e_s}{e_0} \cdot \frac{1}{\left|\frac{\partial \beta}{\partial \omega}\right|}, \qquad (5)$$

the oscillation of frequency ω_0 is decreased in amplitude by the presence of the external signal. If the inequality of (5) is not satisfied, or

$$\left|\omega_s - \omega_0\right| \leqq \frac{e_s}{e_0} \cdot \frac{1}{\left|\frac{\partial \beta}{\partial \omega}\right|}, \qquad (6)$$

the oscillation of frequency ω_0 disappears, and the system acts purely as a regenerative amplifier for the injected signal. This effect, which might experimentally be interpreted as synchronization, will be called pseudosynchronization. It occurrs in a frequency band for which (6) is satisfied, which is the same as that given by Adler[2] for synchronization in a different type of oscillator. Fig. 2 shows, for comparison, the distinction between the phenomena in an amplitude-stabilized oscillator and those described by Adler. In the latter case, the oscillator frequency is "pulled" toward the injected frequency, resulting in a reduction of the beat frequency while the amplitude of the oscillation is constant. In the amplitude-stabilized oscillator, on the other hand, the frequency stays constant while the oscillator amplitude varies according to (4), going to zero at the limits of the pseudosynchronization band.

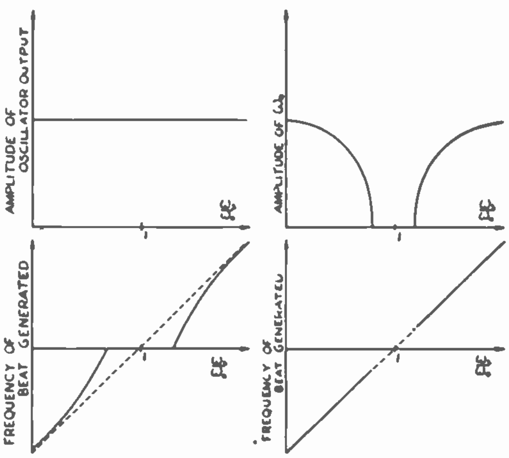

Fig. 2—Comparison of synchronization and locking in an ordinary oscillator (left), with the pseudosynchronization (right) occurring in an amplitude-stabilized oscillator. The upper and lower curves show amplitude and beat-frequency variation, respectively.

Similar results are obtained when the type of amplitude-stabilized oscillator, represented by Fig. 1(b), is analyzed. Results of this analysis for both types of amplitude-stabilized oscillator have been verified experimentally.

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

Quartz Filter Crystals with Low Inductance*

J. J. VORMER†

Summary—**By exciting a harmonic of the Y' wave in a $-18.5°$-rotated X-cut quartz plate, the electrodes of the elementary half-wave sections being electrically connected in parallel, and by choosing for each half-wave section the ratio $l_{z'}/l_{y'}>1$, an appreciable reduction in inductance can be obtained; e.g., tenfold or more. With regard to disturbing frequencies, it will be useful to choose this ratio in the neighborhood of 1.8.**

BAND-PASS FILTERS, composed only of quartz crystals and capacitances, have the advantage that the losses are low and that the construction is simple; on the other hand, they have the disadvantage that the pass band is always relatively narrow. The maximum relative bandwidth that can be obtained with this type of filter is only of the order of about 0.8 per cent.

Therefore, if such a filter is designed for a mean frequency of 100 kc., its absolute bandwidth is, at most, about 800 c.p.s., which is much too narrow for a telephone channel. If a band-pass filter for telephone-channel purposes must be constructed, consisting of quartz crystals and capacitances only, it is necessary to choose at least 500 kc. for the mean frequency. The maximum bandwidth that can be attained is then about 4 kc. For many purposes, it is useful to design the filter unbalanced, as a tee- or pi-filter.

In the frequency range of 100 kc., the crystals are, by preference X cuts which are rotated $-18.5°$ around the X axis and in which the Y' wave is excited. In this type, the Y' dimension $l_{y'}$ of the crystal determines the frequency of the plate. The electrical properties of the plate may further be influenced by the X and by the Z' dimensions; respectively, l_x and $l_{z'}$.

With crystals for filters of 100 kc.; the dimension $l_{y'}$ is sufficiently large, about 25 mm., so that, without much difficulty, it is possible to grind the plate to the correct frequency and to mount it efficiently; moreover, the dimensions l_x and $l_{z'}$ require values which can be realized. Difficulties arise, however, if it is attempted to use this same type of crystal in a filter of about 500 kc.

In the first place, the dimension $l_{y'}$ is much smaller, about 5 mm., so it is much more difficult to grind the plate to the exact frequency. The problem of mounting so small a plate causes complications, as well.

In the second place, the quantities $l_{z'}$ and especially l_x require values which cannot possibly be realized. In this connection, it must be pointed out that the ratio of the inductances of the crystals which are used in the series and the parallel arms of a tee or pi filter is rather considerable, mostly more than 10. Generally, the inductance for an X-cut crystal, which is rotated $-18.5°$ around the X axis can be written:

$$L_k = \alpha \frac{l_{y'} l_x}{l_{z'}}$$

in which equation α is a constant.

As observed before, $l_{y'}$ cannot be chosen freely, as this quantity determines the frequency; for a plate vibrating in its first harmonic, $l_{y'}$ corresponds to one-half wavelength. Thus the inductance can be influenced only by a correct choice of l_x and $l_{z'}$.

In general, plates with high inductances, such as used in the series arm, give the least difficulty, for, in this case, l_x must be chosen large and $l_{z'}$ small, and thus a thick, narrow bar results. This is only limited by the fact that l_x cannot be chosen arbitrarily large, for then the characteristic impedance of the filter becomes undesirably high, while at the same time the possibility arises that the capacitor $C_{p'}$ which must be placed in parallel with the crystal requires a value lower than the inherent capacitance C_p of the electrical equivalent network itself.

It is more difficult to make the inductance of the plates for the parallel arm sufficiently low. In this case, l_x must be chosen small and $l_{z'}$ large. Both methods can only be used on a limited scale. By preference, l_x is chosen not less than 0.1 to 0.2 mm., depending upon the other dimensions of the crystal plate. The manufacturing of a thinner plate is difficult; it is easily broken. Moreover, the decrement of very thin plates is unfavorable. On the other hand, the dimension $l_{z'}$ cannot be made arbitrarily large, for then difficulties will arise with disturbing unwanted resonances.

Mason[1] published graphs for an X cut, as well as for a $-18.5°$-rotated X cut, in which the resonant frequencies of a plate are plotted against the ratios l_z/l_y and $l_{z'}/l_{y'}$. In these graphs, the ratios l_z/l_y and $l_{z'}/l_{y'}$ have values between zero and one.

Mason's measurements demonstrate the fact that an unrotated X cut is little troubled by disturbing frequencies in the region $l_z/l_y<0.2$ and $l_z/l_y=0.5$ to 0.6. In these cases, the undesired resonances have large frequency differences from the main resonance; moreover, they are relatively weak. The graphs indicate, at the same time, that for a $-18.5°$-rotated X cut practically the whole region of $l_{z'}/l_{y'}=0$ to $l_{z'}/l_{y'}=0.9$ can be used, except for a small region in the neighborhood

* Decimal classification: R386.5. Original manuscript received by the Institute, February 14, 1947; revised manuscript received, September 22, 1947.

† Radio Laboratory, the Netherlands Postal Telegraph and Telephone service, The Hague, the Netherlands.

[1] W. P. Mason, "Electrical wave filters employing quartz crystals and elements," *Bell Sys. Tech. Jour.*, vol. 13, pp. 405–452; July, 1934.

of $l_{z'}/l_{y'}=0.23$. These facts explain why, for use in filters, the $-18.5°$-rotated X cut is preferred.

A first method to obtain plates with low inductance which have, at the same time, no trouble with disturbing frequencies, is to unite mechanically into one large plate a number of identical plates, each of which has a favorable value of $l_{z'}/l_{y'}$. In other words, the Y' dimension of the plate no longer corresponds to one-half wavelength of the vibration, but to a number of half wavelengths.

To make such a crystal plate vibrate in the desired harmonic of the Y' dimension, the electrodes must be placed as indicated in Fig. 1. Since, electrically, the

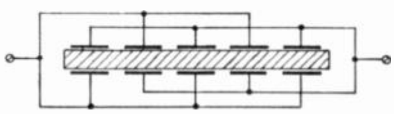

Fig. 1—Electrode connections on a $-18.5°$-rotated X-cut crystal assembly to excite the fifth harmonic of the Y' wave.

elementary parts are connected in parallel, the inductance is lowered by a factor that equals the ordinal number of the harmonic vibration; that is, by 5 in the case shown.[2]

It would be possible to lower the inductance still more if the ratio $l_{z'}/l_{y'}$ could be made larger than 0.9, which, as mentioned before, is a limit because of disturbing frequencies. To investigate if there is any possibility in this direction, we have traced how the graphs, as given

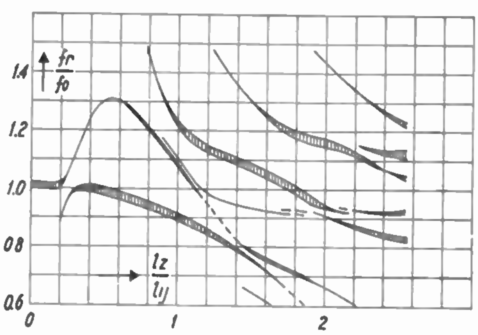

Fig. 2—Resonant frequencies of an unrotated X-cut crystal as a function of the ratio of width to length.

by Mason, run for values of l_z/l_y and $l_{z'}/l_{y'}$. The results are given in Figs. 2 and 3.

In these graphs, as drawn, the resonant frequencies of the plate are plotted against l_z/l_y, respectively, $l_{z'}/l_{y'}$. The frequencies are indicated in a relative measure, in which the frequencies corresponding with l_z/l_y, respectively, $l_{z'}/l_{y'}=0$, are taken as unity. At the same time, the strength of the resonance is indicated. Of the double lines, the lower gives the frequency, while the distance between the lines is a measure of the strength of the vibration. If the strength of the vibration corresponding with l_z/l_y and $l_{z'}/l_{y'}=0$ is taken as unity, the line is drawn full down to 3 per cent on the figures, while for still lower values the line is dotted.

It will be observed that the unrotated X cut, Fig. 2, shows nothing new; for $l_z/l_y>1$, a number of rather strong resonances occur for each value of l_z/l_y. For the $-18.5°$-rotated X cut, things are better, as can be seen from Fig. 3. In the region of $l_{z'}/l_{y'}=1.6$ to 1.8, there are only very weak disturbing frequencies which, at the same time, have a rather large frequency difference from the main resonant frequency. This region can be used effectively for filter crystals. By doing so, the inductance can be lowered once more by a factor of 2, so that, in conjunction with the first reduction of 5 by the use of the fifth harmonic, the total reduction in inductance is about tenfold.

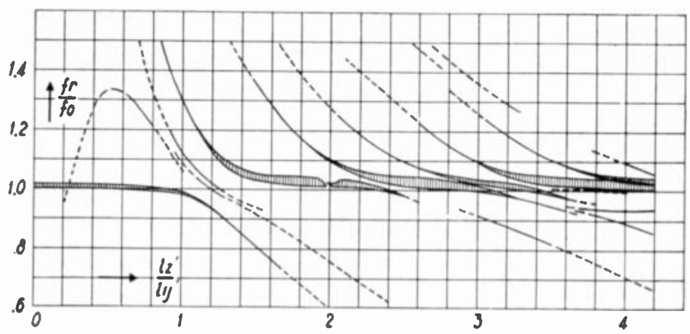

Fig. 3—Resonant frequencies of a $-18.5°$-rotated X-cut crystal as a function of the ratio of width to length.

According to the above principles, a fifth-harmonic $-18.5°$-rotated X-cut filter plate was designed, having a frequency of about 500 kc. and a self-inductance of about 1 henry. The ratio $l_{z'}/l_{y'}:5$ was chosen at 1.8. The dimensions of the plate were $l_x=0.648$ mm., $l_{y'}=25.65$ mm., and $l_{z'}=9.44$ mm.

The constants of the equivalent electrical network were calculated and measured. For the calculation of the frequency, the frequency constant was, according to Fig. 3, taken at $1.02\times2554=2605$ mm. kc.[3] For the calculation of the self-inductance and of the capacitances C_p and C_k, the constants as given by Mason were used.[4] The results were as shown in Table I.

[2] W. G. Cady, "Piezoelectricity," McGraw-Hill Publishing Co., New York, N. Y., 1946; p. 305.

[3] 2554 is the frequency constant of a long and thin bar. See p. 461 of footnote reference 2.

[4] W. P. Mason, "Electro-mechanical Transducers and Wave-Filters," D. Van Nostrand Co., Inc., New York, N. Y., 1943; p. 250.

TABLE I

	Calculated	Measured
f_r	507.797 kc.	508.090 kc.
L_k	0.981 h.	1.036 h.
C_k	0.100 μμfd.	0.095 μμfd.
C_p	13.5 μμfd.	16.8 μμfd. (in holder)

The ratio C_p/C_k is about 175. The temperature coefficient was measured at about $25\times10^{-6}/°C$.

If the same electrical constants were to be obtained with a crystal plate vibrating in the fundamental mode and using the more normal ratio $l_{z'}/l_{y'}=0.7$, the dimensions would become $l_z=0.05$ mm., $l_{y'}=5.22$ mm., and $l_{z'}=3.65$ mm., which cannot be realized in practice.

Positive-Grid Characteristics of a Triode*

GEORGE W. WOOD†, ASSOCIATE, I.R.E.

Summary—**By operating the grid of a triode at a positive potential it becomes a virtual cathode discharging electrons with uniform initial velocity, and thus a recent theory by Jaffé becomes applicable. The positive-grid characteristics of a number of radio receiving tubes are determined and matched with those determined from theory. Agreement, satisfactory under given conditions, is found in the region of low plate voltages.**

Departure of the experimental curves from the theoretical ones is discussed. Practical tubes tested do not, by any means, correspond to the ideal conditions of the theory: the electrodes are not plane; the electrostatic field is not homogeneous; secondary emission from the grid is present; contact potentials exist; and there is always a velocity distribution among the electrons. Nevertheless, the investigation points a way toward a better theory of the triode.

Introduction

Theory concerning the triode is meager, the familiar Van der Bijl[1] equation being determined experimentally and holding over the straight portion of the tube characteristic and for negative grid potentials only. In a recent paper, Jaffé[2] treated the case of the diode in which the electrons have uniform initial velocity. This theory would seem to be applicable to the triode under certain conditions. It was the purpose of this investigation to test the validity of the Jaffé theory under those conditions, which will be discussed later.

The Jaffé Theory and its Present Application

The Jaffé equation is derived for the case where electrons enter, at right angles and with uniform velocity, the space between two infinite parallel planes. The equation is

$$j = V_0^{3/2}\left[\left(1+\frac{E_0}{V_0}\right)^{1/2}+\left(\frac{E_0}{V_0}\right)^{1/2}\right]^3 = [(E_0+V_0)^{1/2}+E_0^{1/2}]^3 \quad (1)$$

where j is introduced as the "reduced current density" by the relation

$$j = \frac{9\pi i d^2}{\left(2\frac{e}{m}\right)^{1/2}}. \quad (2)$$

Here

i = current density
d = distance between emitter plane and receiver plane
e = the charge of the electron
m = the mass of the electron
E_0 = the potential characteristic of the initial electron velocity
V_0 = the potential difference (not necessarily positive) between the emitter plane and the receiver plane.

For a given vacuum tube, the "reduced current density" j is equivalent to the true current density i multiplied by a constant factor, depending upon d. It is this factor which permits the reduction of the formula to one depending upon a single parameter only, i.e., E_0/V_0. The formula holds for that part of the characteristic which is space-charge-limited. As soon as the current reaches the maximum j_{max} given by the supply of the cathode (temperature saturation), the characteristic automatically assumes a constant value. It is this feature, along with the fact that infinite values of space-charge density do not appear, which constitute the main improvements of the Jaffé formula over the Child-Langmuir formula, into which it degenerates in the limiting case $(E_0/V_0)\rightarrow 0$.

In the present paper, the application of the Jaffé theory must be limited to positive grid potentials, for in this manner ideally it should be possible to impart to the electrons, which are emitted from the cathode with their thermal velocities, a uniform velocity. The electrons are accelerated in the field of the positive grid, between the cathode and the grid, and, after passing through the grid meshes, have velocities which differ only in the amounts of their initial velocity—now a very small percentage of difference. The grid becomes, there-

* Decimal classification: R262.1. Original manuscript received by the Institute, June 20, 1947; revised manuscript received, November 17, 1947. Presented, American Physical Society, Southeastern Section, April, 1947, Salisbury, N. C.
† Louisiana State University, Baton Rouge, La.
[1] H. J. Van der Bijl, "Theory of the thermionic amplifier," *Phys. Rev.*, vol. 12, pp. 171–198; September, 1918.
[2] George Jaffé, "On the currents carried by electrons of uniform initial velocity," *Phys. Rev.*, vol. 65, pp. 91–98; February, 1944.

fore, a virtual cathode, discharging into the grid-plate space electrons of nearly uniform velocities, and the tube is then treated as a diode according to the Jaffé equation.

The E_0 of this equation, which is the *e*-volt velocity of the electrons, then becomes the customary E_c of vacuum-tube theory, while the V_0 of the equation becomes the plate potential measured with respect to the grid—the virtual cathode. The following relationship is evident: $E_b = E_c + V_0$. It is because of this relationship that a new method of plotting plate characteristics is presented. In this method, V_0 is chosen as abcissa and

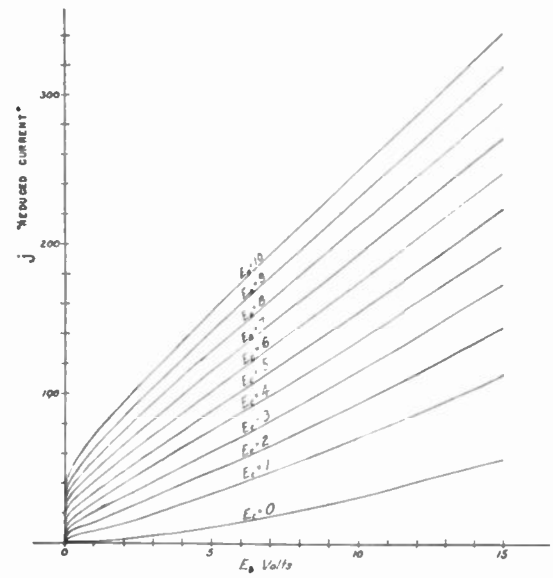

Fig. 1—Theoretical plate characteristics for low voltages, plotted in the usual way.

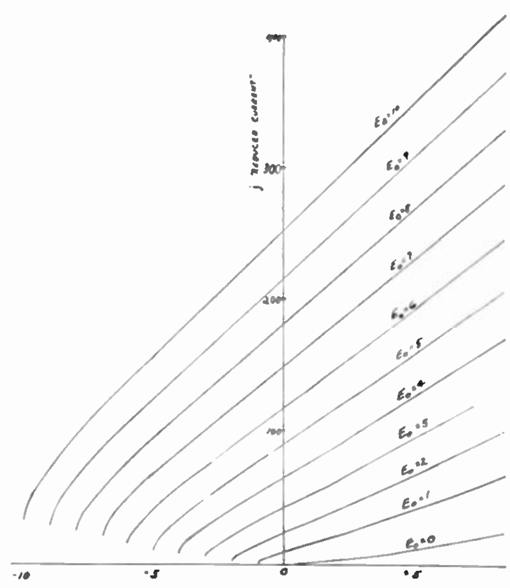

Fig. 2—Theoretical plate characteristics for low voltages, plotted by the new method.

E_0 as parameter, and the characteristic extends to negative values of V_0 with the limit $V_0 = -E_0$. The new method is used throughout this paper, and results in a better definition between curves at low plate potentials.

Since experimental agreement with the Jaffé theory was sought for in conventional radio receiving tubes, which by no means correspond to the ideal conditions of the theory, it soon became evident, for reasons which will be discussed later, that such agreement would most likely be found in the region of low plate potentials. Figs. 1 and 2 show the theoretical plate characteristics plotted in the conventional way and in the new way.

It should be noted that the theoretical plate characteristics start with a finite value and a vertical tangent for all positive grid potentials. If there were no space-charge effect, the current would be equal to j_{max} even for the limiting value $V_0 = -E_0$. Because of the space-charge effect, however, this value is reduced to $E_0^{3/2}$. In practical cases there will always exist a velocity distribution with velocities ranging from zero to a maximum value, and, as might be anticipated, the characteristics will not start with a finite value of the current at $V_0 = -E_0$, but will descend to zero.

Experimental Measurements

The experimental arrangement was identical with that used in determining the static characteristics of vacuum tubes, as can be seen from the schematic diagram, Fig. 3. Certain precautions were observed in the taking of data. If the grid was operated at too high a positive potential while the plate voltage was low or

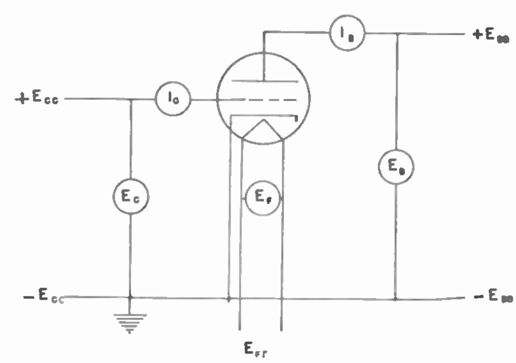

Fig. 3—Schematic diagram of the experimental arrangement.

zero, there was the possibility (and sometimes actuality) of the grid being heated by its own current and becoming an actual emitter of electrons. This was one reason for performing the experimental work in the region of low grid and plate potentials. At all times cathode current was limited to a value that was considered safe, although in practically all test runs the specified maximum for the plate current was exceeded.

Tubes for the determination of positive-grid characteristics were selected from those readily available as radio receiving tubes. While it was found that there are many triodes available, a large majority of the various types are duplicates, with the exception of filament voltage and current requirements. The selection was thus narrowed down to such representative types as the following: 45, 26, 2A3, 6J5GT, and 76. In order that additional data might be secured, several tubes of more than three elements were tried, with the additional elements so connected externally as to cause the tube to act as a triode. In this line of investigation the type-6AG7 tube, with the suppressor grid and screen grid connected to the plate, was found to be most satisfactory.

Discussion and Comparison Between the Theory and Experimental Results

In attempting to fit characteristics observed in commercial tubes with those determined from the theoretical formula which holds under highly idealized conditions, it must be remembered that there are many circumstances which might be expected to prevent an accurate agreement. The most important circumstances are:

(a) The electrons in the actual tubes will not have really uniform velocities, even under the conditions previously outlined.

(b) The field in the neighborhood of the grid (which is acting as a virtual cathode) will be very far from homogeneous.

(c) The electrons will therefore leave the plane which idealizes the grid, not only in normal directions.

(d) Since some of the lines of force which emerge from the real cathode terminate on the grid, electrons will be dragged into the grid beyond the number of those which are prevented by the space charge from entering the space between the grid and plate. The number of electrons thus lost will depend greatly on the size of the grid meshes and on the values of E_0 and V_0.

(e) Contact potentials may and do occur in the tubes and will affect the experimental curves strongly, particularly in the domain of low values of E_0 and V_0.

(f) Since the grid is attracting electrons by its positive potential, it is quite likely that secondary electrons will be liberated, and will thus add to the plate current. It should also be observed that, in adapting the experimental curves to the theoretical ones, only *one* constant is available—that which reduces the observed currents to the "reduced current density" of the theory. This one factor reduces the whole set of curves, and therefore any agreement obtained offers a very severe test of the theory.

Under these circumstances, the best to be expected is semiquantitative agreement between the theoretical and experimental curves. A close examination shows this to be true. Comparing the behavior of the experimental and theoretical curves (see Figs. 2, 4, and 5), a complete qualitative agreement can be observed; the characteristics begin approximately at those negative values of V_0 which reduce the initial velocities of the electrons to zero, cut the zero-voltage axis at positive values of plate current I_b which increase with the initial velocity given the electrons, and finally become very nearly parallel for all velocities.

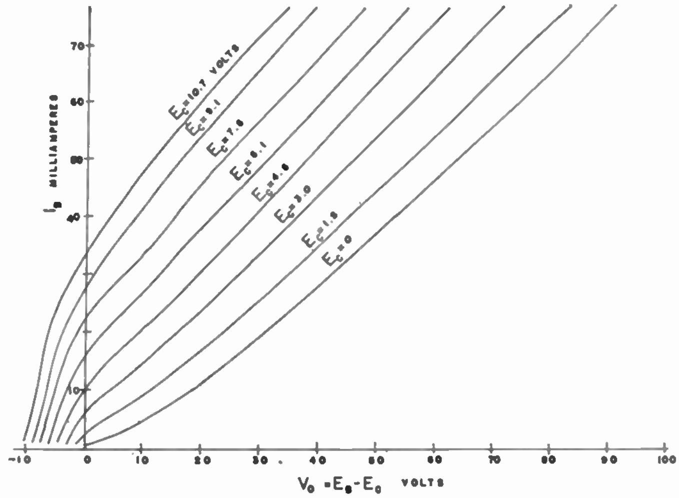

Fig. 4—Experimental plate characteristics for a type 2A3 tube.

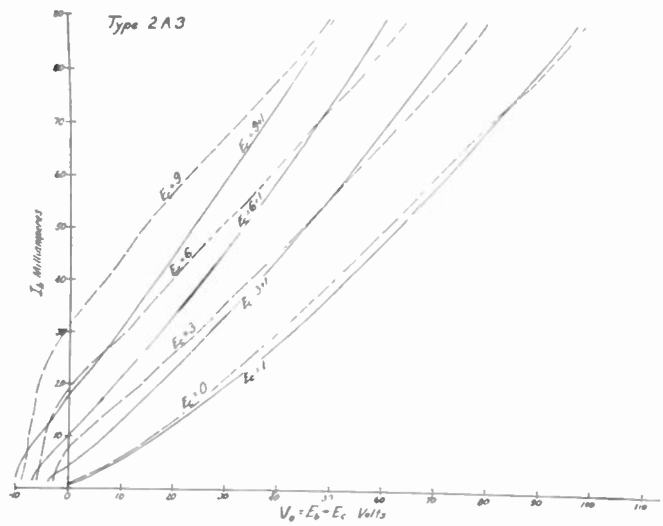

Fig. 5—Experimental and theoretical plate characteristics plotted over a wide range of plate voltage, for a type 2A3 tube. The theoretical curves have been multiplied by a factor of 0.070, and a contact potential of +1 volt on the grid has been assumed.

According to theory, the currents observed for $V_0=0$ (i.e., $E_b=-E_c$) should be given by $j_{V_0=0}=8E_0^{3/2}$ and in a particular tube be proportional to $E_0^{3/2}$ (or to the third power of the initial velocity). This consequence of the theory is verified with fair accuracy, as is shown in Table I. Deviations are strongest in those cases where secondary emission is strong, as we will see below.

Attempts to obtain numerical agreement over wide ranges of potentials met with serious difficulties in all cases. These difficulties begin with the ordinary Child-Langmuir characteristics, i.e., for $E_0=0$. It is well known that in the relation between current and plate voltage for diodes (or triodes used as diodes), the exponent almost never shows the theoretical value 3/2,

TABLE I
THE DEPENDENCE OF THE CURRENT ON THE GRID POTENTIAL FOR $V_0=0$

Tube Type	E_0	j	$E_0^{3/2}$	$\frac{j}{E_0^{3/2}}$
26	3	2.25	5.196	0.434
	6	5.0	14.697	0.340
	9	8.85	27.000	0.328
45	3	3.3	5.196	0.635
	6	7.55	14.697	0.515
	9	12.25	27.000	0.454
76	3	3.7	5.196	0.635
	6	7.1	14.697	0.483
	9	12.5	27.000	0.463
2A3	3	7.9	5.196	1.52
	6	18.5	14.697	1.26
	9	32.5	27.000	1.24
6AG7	3	9.9	5.196	1.91
	6	25.05	14.697	1.71
	9	48.0	27.000	1.78
6J5GT	3	3.25	5.196	0.625
	6	8.4	14.697	0.572
	9	16.0	27.000	0.593

and furthermore changes with plate potential. The same might be expected if a triode is operated with $E_0=0$, since this arrangement corresponds to the assumption made in Child and Langmuir's theory; namely, that the electrons leave the cathode with no velocity. Measurements made confirmed these observations. In consequence of these circumstances, the curves for $E_0=0$ cannot be considered standard curves for the calculation of the reduction factor. Rather, this factor has to be determined in a way which reduces the whole set of curves for best agreement. Since the currents for $V_0=0$ show the necessary theoretical dependence on E_0 (as indicated above), the reduction was performed in such a way that these currents were made to coincide approximately for the experimental and theoretical sets.

Fig. 5 shows the theoretical and experimental curves plotted over a wide range of plate voltage. The attempt is made to match the two sets of curves as nearly as possible; however, the initial hump in the experimental curves prevents any close agreement, in this wide range. The same difficulty was encountered in all of the tube types tested. In the calculation of the theoretical curves represented in this figure, a contact potential of +1 volt on the grid had to be assumed in order to make the $E_0=0$ curve fit.

It was later found that, by matching the experimental and theoretical curves in the range of V_0 below 20 volts, much closer agreement could be obtained. Fig. 6 illustrates such agreement. Experimental points were obtained (as indicated in the figure) with tube types 2A3, 76, 6J5GT, 45, and 26. Since all triode plate characteristics are very similar, they can be brought into near coincidence by multiplication by a constant factor which depends upon the construction of the tube and the temperature of the cathode, but which was chosen experimentally so as to give the best agreement between curves in the region in question.

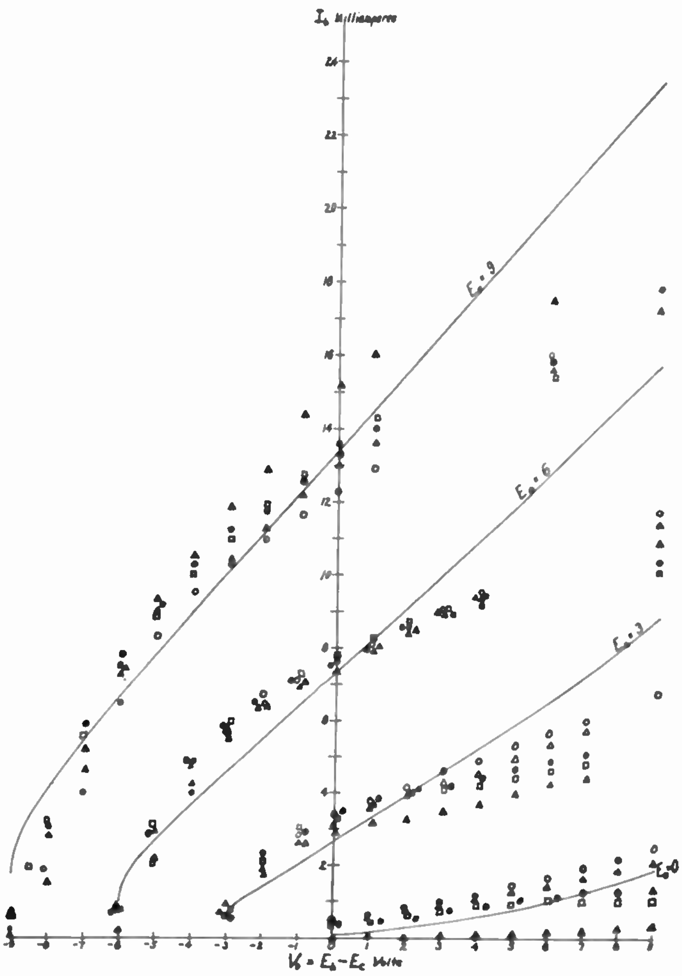

Fig. 6—Comparison between theoretical and experimental characteristics for 6J5GT, 26, 76, 2A3, and 45 tubes, using low plate voltages. Here the theoretical values have been multiplied by 0.062 to bring them to milliamperes.

Key:
○ = Type 45 (not reduced)
△ = Type 2A3 (×.4)
□ = Type 56 (×1.2)
▲ = Type 6J5GT (×.9)
● = Type 26 (×1.5)

A type 6AG7 pentode was caused to act like a triode by connecting the suppressor grid and the screen grid to the plate, and plate characteristics were determined. It was not possible to secure good agreement between theory and experiment over a wide range of values, but in the region of V_0 below 20 volts good agreement is obtained, as is shown in Fig. 7.

As for the systematic deviations of the theoretical curves from the experimental ones, inspection of Figs. 3 through 7 will confirm the following observations:

(a) In all cases, even in the low-voltage region, points determined experimentally fell below the theoretical curves for the first few volts of rise of plate voltage. This depression increased with increasing grid potentials, and was obviously due to the grid attracting electrons which would otherwise flow to the plate. Depending upon the construction of the grid and its potential, the grid current became quite large.

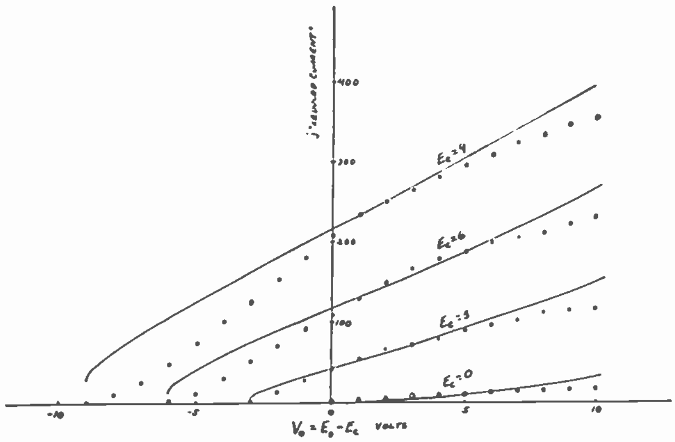

Fig. 7—Comparison between theoretical and experimental plate characteristics for low plate voltages, type 6AG7 tube. The experimental values (O) have been multiplied by a factor of 4.33.

(b) A pronounced hump, following the initial depression, is found in all of the experimental curves. This is quite probably due to secondary emission from the grid. Such emission would not be evident when the grid potential is zero or negative (few electrons strike the grid), nor to any degree while $V_0 < E_0$ (the secondary electrons return to the grid); but for $V_0 \geqq E_0$ most of the secondary electrons released would flow to the plate, adding to the plate current.[3,4] This would account for the hump in the characteristics very well. The contribution to plate current by these electrons can only be guessed, but comparison between this hump and the depression due to secondary emission from the plate of, and found in the plate characteristics of, the old type 24-A tetrode (which was noted for this effect) is suggested.

(c) The theoretical curves invariably rise above the experimental ones for voltages above $V_0 = 20$ volts. This deviation is rather hard to account for. It can hardly be attributed to deviation from the 3/2-power law. It is quite possible that the magnitude and extension of the secondary-emission effect noted above is greater than originally anticipated.

(d) The Jaffé equation is derived for parallel planes. Tube types 26, 2A3, 45, and 6J5GT had electrodes which were approximately plane, while types 76 and 6AG7 had cylindrical electrodes. The use of the theoretical formula for cylindrical arrangements appeared legitimate since the characteristics obtained with tubes of different geometry could be reduced to a common pattern, as is best shown in Fig. 6.

(e) It is quite likely that contact potentials existed within the tubes. Some attempts at matching the theoretical and experimental curves by assuming a small contact potential were made. This procedure met without any great degree of success, for in order to provide any closer agreement by this means the contact potential would have to vary with the grid voltage. Since there was no logical basis for such an assumption, attempts at correction by this method were abandoned.

Suggestions for Improvement

This work is by no means intended as a complete verification of the Jaffé theory. Rather, it is preliminary and indicates the direction which further investigation should take. Vacuum tubes used in the experimental work were those readily available, but their construction in no sense approximated the ideal conditions of the theory. It is suggested that succeeding experimental evidence be based upon tubes of special construction, with particular emphasis upon the structure and spacing of the tube elements. Effects due to secondary emission should be reduced to a minimum by careful selection of the tube electrodes and treatment of their surfaces.

On the other hand, an attempt should be made to modify the theory in such a way that it takes into account more realistically the conditions in actual discharge tubes. It is therefore desirable to extend the derivation not only to the cylindrical arrangement, but also to the case where the grid is treated as an actual grid, allowing for the nonhomogeneity of the field near the grid, and for penetration of the field.

[3] The possibility of secondary emission taking place under such conditions as these is confirmed, for example, in the following reference: Sir J. J. Thomson and C. P. Thomson, "Conduction of Electricity through Gases," vol. 2, University Press, Cambridge, 1933, pp. 183, 187, 188, 189, 190.

[4] H. F. Dart, "Vacuum-Tube Testing and Design," International Textbook Co., Scranton, Pa., 1939; pp. 15, 45.

Contributors to Waves and Electrons Section

Wayne Coy

Wayne Coy was born in Shelby County, Ind., on November 23, 1903. He received the B.A. degree in 1926 from Franklin College in Indiana, and in 1940 was granted the honorary degree of Doctor of Letters by the same institution. Mr. Coy joined the staff of the Franklin, Indiana, *Star* in 1919, and in 1926 became its city editor. Later he edited and published the *Delphic Citizen*.

After two years as anonymous assistant to President Roosevelt, in 1942 Mr. Coy assumed the Assistant Directorship of the Federal Budget. Two years later he left to become assistant to the owner of the Washington *Post*, where he was also radio editor of stations WINX and WINX-FM. He was one of the moving spirits of FM Broadcasters, Inc., forerunner of the present FM Association, of which he is a board member. On December 29, 1947, Mr. Coy was appointed Chairman of the Federal Communications Commission and he is now serving in that post. He is a member of the American Academy of Political Science, Phi Delta Theta, and Sigma Delta Chi.

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William C. Galloway

William C. Galloway (S'44–A'45) was born in Tacoma, Wash., on May 14, 1922. He received the B.S. degree from the University of Washington in 1944, and the S.M. degree from the Massachusetts Institute of Technology in 1948, both in electrical engineering.

From 1944 to 1946 Mr. Galloway was employed by the Applied Physics Laboratory of the University of Washington, and from 1946 to 1948 he was a research assistant in the electrical engineering department of M.I.T., engaged in research in microwave communications. At the present time he is employed in the Physical Research Laboratory of the Boeing Aircraft Company, Seattle, Wash.

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For a biography and photograph of J. E. Hacke, see page 741 of the Proceedings of the I.R.E., this issue.

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Robert B. Monroe

Robert B. Monroe (A'42–SM'46) was born in Brooklyn, N. Y., on October 17, 1908. He attended Pratt Institute from 1937 to 1942. In 1934, Mr. Monroe was employed by the technical operations department of the Columbia Broadcasting System, and in 1936 he was transferred to the general engineering department, where he has been continuously employed except for the war years.

From 1942 to 1945, Mr. Monroe was associated with the Radio Research Laboratory, Harvard University, which was sponsored by the Office of Scientific Research and Development. There he served successively as head of the Planning Department, head of the Standards Laboratory, and assistant to the executive engineer. During the winter and spring of 1944–1945, he served as technical observer for the U. S. Army Air Forces in the China, Burma, and India Theater of Operations.

In 1945, Mr. Monroe rejoined the CBS general engineering department. Currently, he is a project engineer in the audio-video division.

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Charles A. Palmquist (A'46) was born on September 29, 1917 at Laramie, Wyo. He received the B.S. degree in electrical engineering in 1938 from Purdue University. From 1938 to 1941, he was employed as a design engineer by the RCA Manufacturing Company.

Mr. Palmquist served with the U. S. Navy from 1941 to 1945, during which time he attained the rank of lieutenant commander. His tour of duty consisted of engineering officer afloat, officer-in-charge of an underwater sound station, instructor, and assistant officer-in-charge of the Underwater Sound School at San Pedro, Calif. In 1945 he became associated with the Columbia Broadcasting System as an engineer in the General Engineering Department. Mr. Palmquist's work has been chiefly concerned with a. f. systems design.

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For a biography and photograph of Pierre R. Aigrain, see page 84 of the January 1948, issue of the Proceedings of the I.R.E.

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Harold B. Richmond

Contributors to Waves and Electrons Section

Harold B. Richmond (A'14–M'23–F'29) was born on March 22, 1892, in Medford, Mass. He received the S.B. degree from the Massachusetts Institute of Technology in 1914, and was given the D.Eng. degree by Norwich University, Northfield, Vt., on June 2, 1947, for his pioneer radio service, his work on guided missiles in World War II, and his interest in engineering education. He has been president of the Radio Manufacturers Association, and was also elected board chairman of the Scientific Apparatus Makers of America.

Joining the General Radio Company organization in 1919, he became secretary in 1921, assistant treasurer in 1924, treasurer in 1926, and chairman of the board in 1944, which position he now holds.

Dr. Richmond has served on the following I.R.E. Committees: Admissions, Nominations, Preparedness, Registration of engineers, and Standardization. He is a fellow of the American Institute of Electrical Engineers.

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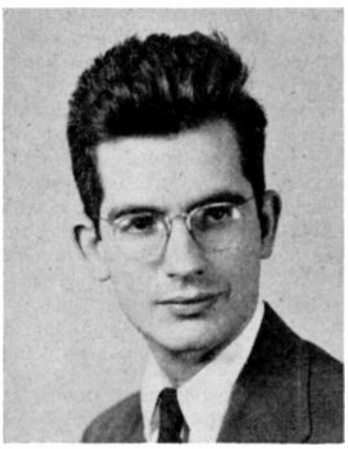

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William G. Tuller (S'37–A'40–M'45) was born in Rutherford, N. J., on September 8, 1918. He received the S.B. and S.M. degrees in electrical engineering from the Massachusetts Institute of Technology in 1942. From 1941 to 1947 he was on the staff of the Raytheon Manufacturing Company as development engineer and consultant. Since July of 1947, Mr. Tuller has been a project engineer at Melpar, Inc. He is a member of Sigma Xi.

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For a photograph and biography of Jan J. Vormer, see page 794 of the August, 1947, issue of the Proceedings of the I.R.E.

A. H. Waynick

A. H. Waynick (J'25–A'27–SM'46) was born on November 9, 1906, at Spokane, Wash. He received the B.S. degree in 1935, and the M.S. degree in physics in 1937, from Wayne University. He was a research student at Cambridge University during 1938 and 1939, and received the D.Sc. degree in communications engineering in 1943 from Harvard University.

During 1944 and 1945 Dr. Waynick was a research associate at the Harvard University Underwater Sound Laboratory. In 1945 he became an associate professor in engineering research at the Ordnance Research Laboratory of The Pennsylvania State College, advancing to professor in 1946.

Dr. Waynick is a member of Sigma Xi and of the American Institute of Electrical Engineers.

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George W. Wood

For a biography and photograph of Everard M. Williams, see page 87 of the January, 1948, issue of the Proceedings of the I.R.E.

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George W. Wood (A'45) was born at Warrensburg, Mo., in 1919, and received the B.S. degree from Central Missouri State College in 1941. He was employed in the crystal laboratories of the Aireon Corporation, before accepting a position as instructor in physics with Louisiana State University in the fall of 1943. In addition to his teaching duties, which included two semesters with the department of electrical engineering, he carried on graduate work and received the M.S. degree in 1946.

Mr. Wood at present is an instructor in physics at Louisiana State University. He is a member of Pi Mu Epsilon and the American Physical Society.

❖

F. P. Zaffarano

F. P. Zaffarano was born at Cleveland, Ohio, on November 1, 1920. He received the B.S. degree in electrical engineering from the Case School of Applied Science in 1942. A staff member of the Radiation Laboratory at M.I.T. from 1942 to 1946, he received the Army's Medal of Freedom for his work on microwave-beacon blind-bombing equipment while with the European branches of the Radiation Laboratory from 1943 to 1945.

Returning to graduate study with a research assistantship in the Research Laboratory of Electronics at M.I.T., Mr. Zaffarano received the S.M. degree in electrical engineering in 1947. Since leaving M.I.T., he has been working on Air Traffic Control problems in the development laboratory of the General Railway Signal Company of Rochester, N. Y. He is a member of Sigma Xi and of Eta Kappa Nu.

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 I.R.E.

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. U.D.C. numbers marked with a dagger (†) must be regarded as provisional.

ACOUSTICS AND AUDIO FREQUENCIES

016:534 **1223**
References to Contemporary Papers on Acoustics—A. Taber Jones. (*Jour. Acous. Soc. Amer.*, vol. 19, pp. 997–1001, November, 1947.) Continuation of 908 of May.

534.32:621.395.813 **1224**
What Is Good Reproduction? (*Wireless World*, vol. 54, p. 20, January, 1948.) British Sound Recording Association discussion opened by M. G. Scroggie. Quantitative assessment of good reproduction is difficult, because the subjective opinion of the listener is necessarily involved. The ear appears to detect distortions too small to be measured. Distortions arising in loudspeakers were discussed briefly.

534.321 **1225**
The Perception of Pitch—J. F. Schouten. (*Philips Tech. Commun.* (Australia), pp. 11–20; October, 1946.) Reprint of paper from *Philips Tech. Rev.* Noted in 1425 of 1942.

534.321.9:534.22 **1226**
A Precision Ultrasonic Interferometer for Liquids and Some Velocities in Heavy Water—D. R. McMillan, Jr., and R. T. Lagemann. (*Jour. Acous. Soc. Amer.*, vol. 19, pp. 956–960; November, 1947.) A stabilized beat-frequency oscillator is used to generate the ultrasonic waves in the liquid. Nodal positions are detected by means of a tube voltmeter. Measurements of velocities in acetone, benzene, and distilled water are compared with those of earlier workers and new measurements for heavy water at 5°, 10°, and 15° C are tabulated.

534.41 **1227**
Audiometry of Normal Hearing—C. J. LeBel. (*Audio Eng.*, vol. 31, pp. 23–25, 37; November, 1947.) Brief details of a typical audiometer precede a description of its applications in medical, industrial, and technical fields.

534.756+534.78 **1228**
New Possibilities in Speech Transmission—D. Gabor. (*Jour. I. E. E.* (London), part III, vol. 94, pp. 369–387; November, 1947. Discussion, pp. 387–390.) Two methods of frequency compression are discussed. Experimental details are given of a device for testing the quality of compressed and re-expanded speech. Compression to one-half gives full intelligibility but roughness; compression to one-sixth is intelligible but monotonous; greater compression causes loss of intelligibility. The causes of roughness and monotony are analyzed; only certain "preferred frequencies" are transmitted correctly. The reproduction is good only if one of these coincides with the pitch of the speech. In a suggested improved system, the preferred frequencies are not fixed, but adjust themselves automatically to the pitch. The concept of phase is analyzed. Theoretically two independent messages can be sent through the same channel by a system termed "quadrature transmission." See also 1057 of 1947.

534.76+534.85 **1229**
Stereophonic 2-Channel Transmission with the Magnetophon—W. Lippert. (*Funk und Ton*, pp. 173–190 and 236–250; October and November, 1947.) The general principles of stereophony are explained and the principal published theoretical and experimental results are reviewed. The construction of magnetophon apparatus for 2-channel working is described and test results are given which show that the apparatus can be improved appreciably in some respects, though, in general, it is well adapted for stereophonic transmission. Comparison tests of normal single-channel and stereophonic 2-channel reproduction of music and speech are discussed at length. The 2-channel system appears to have definite advantages. Other possible applications of the 2-channel magnetophon include broadcasting and high-fidelity reproduction of music.

534.78:621.396.662.32 **1230**
Audio Filters for the Speech Amplifier—Galin. (*See* 1336.)

534.84 **1231**
Construction and Design of Parmly Sound Laboratory and Anechoic Chamber—P. J. Mills. (*Jour Acous. Soc. Amer.*, vol. 19, pp. 988–992; November, 1947.) General description and construction details. The 40-ton anechoic chamber is suspended on neoprene pads and has a natural frequency of about 4 and one half c.p.s. The inner surfaces are lined with wedge-shaped fiberglas blocks, and are designed to have 99 per cent absorption for frequencies above 115 c.p.s. See also 3529 of 1946 (Beranek and Sleeper).

534.845 **1232**
The Application of Helmholtz Resonators to Sound-Absorbing Structures—V. L. Jordan. (*Jour. Acous. Soc. Amer.*, vol. 19, pp. 972–981; November, 1947.) Theoretical and practical considerations show that sound absorbing structures using Helmholtz resonators can often be used advantageously, whether the problem is to obtain flat reverberation characteristics, to damp pronounced singularities, or to absorb sound in certain low-frequency ranges. Sizes of apertures used for absorption have been found empirically and it is shown that they do not conform to existing theory. The need for accurate formulas for the resistance term of resonators is stressed.

534.851 **1233**
The Dynamic Noise Suppressor—J. D. Goodell. (*Audio Eng.*, vol. 31, pp. 7–10, 45; November, 1947.) Design principles and circuit details for suppressing background noise associated with the electrical reproduction of phonograph records. Control voltages proportional to the total incoming signal and noise are derived for several selected frequency bands, and are applied through reactance tubes to control the frequency ranges passed by the system. The circuits are so arranged that the pass band is at its minimum value when there is no signal. A complete account was noted in 3006 of 1947 (Scott).

534.851:621.395.625.2 **1234**
The Design of a New Lacquer Recording Stylus—I. L. Capps. (*Audio Eng.*, vol. 32, pp. 18–20, 42; January, 1948.) A modified design which provides two or three burnishing facets at different angles along the cutting edge. This ensures adequate burnishing of the groove walls over a greater range of groove slopes, and thus reduces the playback noise. See also 616 of 1947.

534.851.6:621.395.828.1 **1235**
Experimental Noise Suppressor—C. D. Cole. (*Audio Eng.*, vol. 32, pp. 9–12; January, 1948.) Phonograph-needle hiss does not occur at frequencies much below 1.5 kc.; at greater frequencies, it has a fairly constant amplitude of approiximately 40 db below the program peaks. The suppressor, described first, separates the program into four portions by means of band-pass filters covering the octaves 0 to 1.5

kc., 1.5 to 3 kc., 3 to 6 kc., and 6 to 12 kc. Germanium rectifiers, in all except the lowest frequency channel, then suppress both program and noise below a certain selected amplitude. Harmonic distortion is removed by a further set of octave band-pass filters before the channels are recombined.

534.86:534.322.1 1236
Frequency Range Preference for Speech and Music. H. F. Olson. (*Broadcast News*, pp. 28–32; September, 1947.) Full account of the tests already noted in 10 of February.

534.861 1237
New C.B.S. Program Transmission Standards—H. A. Chinn and P. Eisenberg. (Proc. I.R.E. vol. 35, pp. 1547–1555; December, 1947.) Full analysis of the results of experiments conducted to determine (a) the relative levels at which speech and music should be transmitted, and (b) the range within which the peak levels should lie. As a result of the tests the C.B.S. has adopted new maximum peak levels and introduced minimum levels below which the peaks should not fall. See also 3567 of 1945 (Chinn and Eisenberg.)

534.861.1 1238
Recording Studio 3A—G. M. Nixon. (*Broadcast News*, pp. 33–35; September, 1947.) Discusses the acoustical design problems in remodelling a studio for broadcast transcription and recording. Adjustable acoustical elements are used to provide a change of reverberation time of about 2 to 1. The optimum combination of diffusely reflecting surfaces and absorbent areas is considered.

621.395.61:621.395.623.7 1239
Microphones for Loudspeaker Equipment—E. M. Philipp. (*Radio Tech.* (Vienna), vol. 23, nos. 8 and 9, pp. 411–418; 1947.) An account of the construction of various types of microphone and of their frequency characteristics, when used singly or in combination, with suitable amplifiers.

621.395.623.7 1240
"An F.M. Quality" Speaker—G. E. Rand. (*Broadcast News*, pp. 24–27; September, 1947.) Uses two cones having the same vertical angle and apex. The diameter of the low-frequency cone is 15 inches, and that of the high-frequency cone, 2 inches. A very flat frequency characteristic over a wide range, low side tone, and good polar diagram at all frequencies are claimed. The speaker is the outcome of work by Olson and Preston (2664 of 1947).

621.395.623.8+621.396.61]:621.318.572 1241
An Experiment in Voice Controlled Relays—Wortman. (*See* 1512.)

621.395.625.2 1242
Feedback Recording Head Giving Low Intermodulation—E. Cook. (*Tele-Tech*, vol. 6, pp. 46–49, 102; November, 1947.) Controllable degenerative feedback improves frequency response and stability in disk-recording gear. A magnetic cutter is used because of its cheapness and strength. The difficulties of securing efficient feedback from the last stage of the cutter amplifier are considered. Complete circuit and design details are given.

621.395.625.2 1243
Commercial Disc Recording—(*Wireless World*, vol. 54, p. 67, February, 1948.) Brief summary of I.E.E. lecture entitled, "Commercial Disc Recording and Processing," by B. E. G. Mittell. Proposals were made for the standardization of groove and stylus shape and of recording characteristics. In the discussion these proposals were, in general, approved. It was also generally agreed that an extended high-frequency response was desirable. The use of vinyl plastics for the manufacture of records, and the performance of sapphire points were also discussed.

621.395.625.3 1244
Field Measurements on Magnetic Recording Heads—D. L. Clark and L. L. Merrill. (Proc. I.R.E., vol. 35, pp. 1575–1579; December, 1947.) A method is described for measuring relative values of the magnetizing force along the path of the wire traversing a recording or reproducing head. Field distribution curves are shown. The frequency response is calculated and compared with the measured values. The high-frequency response depends on the sharpness of cutoff on the "leaving" side of the gap and is independent of the shape on the "approaching" side.

621.395.92 1245
Government Hearing Aid—(*Wireless World*, vol. 54, pp. 11–12; January, 1948.) Summary of Medical Research Council Special Report No. 261: "Hearing Aids and Audiometers," published by H. M. Stationery Office. Optimum response, amplification, and output were determined from numerous tests covering all types and degrees of deafness. Batteries and connectors should be standardized. Circuit and performance details are given of two prototypes made at the Post Office research station; one has a lightweight moving-iron receiver and the other a piezoelectric insert receiver. Appendixes deal with audiometers and objective tests for hearing aids. For other summaries see *Brit. Med. Jour.*, pp. 916–917; December 6, 1947 and 1246 below.

621.395.92 1246
Hearing Aid Development—(*Elec. Times*, vol. 112, pp. 687–688; December 11, 1947.) Discussion of an I.E.E. paper entitled "Speech Communication under Conditions of Deafness or Loud Noise," by W. G. Radley, and of the Medical Research Council's Special Report No. 261; see also 1245 above. Hearing aids designed to have a response curve which falls off at frequencies below 1000 c.p.s. were tested experimentally on 63 subjects at one clinic and 165 at another. A definite improvement in intelligibility was obtained when the amplification was decreased for frequencies below 750 c.p.s. at a rate of 12 db per octave. Further, the amplification above 4000 c.p.s. could be reduced at the rate of 18 db per octave. Between 750 and 4000 c.p.s., the response should be level, or should increase slowly to a peak value at 4000 c.p.s. about 12 db greater than the 750-c.p.s. amplification.

621.395.92 1247
Smallest Hearing Aid Uses Printed Circuits—(*Radio Craft*, vol. 19, pp. 66–67; January, 1948.) Description, with photographs and circuit diagram, of an instrument whose case measures only 4 and one-half inches ×2 and three-eighths inches×seven-eighths inch and contains amplifier and batteries.

621.395.92 1248
The Influence of Body-Baffle Effects on the Performance of Hearing Aids.—R. H. Nichols, Jr., R. J. Marquis, W. G. Wiklund, A. S. Filler, C. V. Hudgins, and G. E. Peterson. (*Jour. Acous. Soc. Amer.*, vol. 19, pp. 943–951; November, 1947.) Discussion of the effect of the wearer's person on the response of a hearing aid. This baffle effect has been studied under free- and diffuse-field conditions for several different hearing aids and wearers. It does not depend greatly on the size of the wearer, nor does it appreciably reduce intelligibility. For each type of hearing aid, worn at the center chest position in a free field, the curve relating response and frequency is plotted. In general, there is a broad peak, about 5 db in height, for the frequency range 100 to 1000 c.p.s. and a relatively narrow valley, 15 to 20 db in depth, for the frequency range 800 to 2000 c.p.s. In a diffuse sound field, the body-baffle effect is very small.

ANTENNAS AND TRANSMISSION LINES

621.315.212:621.392.029.64 1249
Plane Discontinuities in Coaxial Lines—J. W. Miles. (Proc. I.R.E. vol. 35, pp. 1498–1502; December, 1947.) The equivalent circuit is established as a simple shunt capacitance, which is calculated for concentric changes of cross section and concentric disks. In order to use the results of the analogous discontinuities in parallel-plate guides, "equivalent radii" are asymptotically calculated; the results are sufficiently accurate for most practical applications. See also 634 of 1947.

621.392.012.2 1250
Construction of Circle Diagrams and Their Use in solving Certain Transmission Line Problems—I. T. Sokolov. (*Radiotekhnika* (Moscow), no. 7, pp. 57–69; 1947, In Russian.) Discussion of the use of circle diagrams for calculating the input impedance of a line, the coefficients of standing and traveling waves, etc.

621.392.029.64 1251
On Wave Propagation in Waveguides—L. de Broglie. (*Radio Tech. Dig.* (*Franç*)., vol. 2, pp. 20–25; February, 1948.) All the solutions normally obtained for waveguide propagation can be derived by the superposition of plane waves of a certain type. An expression for the phase velocity is then easily deduced. Two methods of treating the propagation of energy along a waveguide are considered. These methods, whose equivalence is not obvious, are shown to give the same result. Certain of the formulas derived show close analogy with wave mechanics and it appears that the study of waveguide theory is of great interest not only in radio technique but also from a general scientific standpoint.

621.392.029.64 1252
On the Penetration of an Electromagnetic Field through a Diaphragm in a Waveguide—M. I. Kontorovich. (*Zh. Tekh. Fiz.*, vol. 17, no. 3, pp. 269–282; 1947. In Russian.) An infinitely long tube is considered, made of perfectly conducting material and divided into two parts by a perfectly conducting diaphragm with a small central aperture (Fig. 1). It is assumed that an electro-motive wave is passing from one part of the tube to the other. A differential equation (3) is derived and methods for its solution are indicated. Boundary conditions are discussed and various constants determined. Finally, a general equation (18), determining the field set up by the wave after passing through the diaphragm, is derived. Particular cases are considered and the accuracy of the proposed solutions is verified experimentally.

621.392.029.64 1253
The Theory of Disk-Loaded Wave Guides—E. L. Chu and W. W. Hansen. (*Jour. Appl. Phys.*, vol. 18, pp. 996–1008; November, 1947.) "The properties of circular waveguides loaded with apertured disks are discussed both qualitatively and quanitatively. Formulas and curves are given for various quantities including the wave and group velocities, the attenuation, and the power flow."

621.392.029.64:621.317.791 1254
Simple Measuring Equipment for Flexible Waveguides—Winchell. (*See* 1417.)

621.392.029.64:621.392.4 1255
An Adjustable Wave-Guide Phase Changer—A. G. Fox. (Proc. I.R.E. vol. 35, pp. 1489–1498; December, 1947.) The properties are discussed of two basic differential phase-shift sections which produce differential delays of 90° and 180° respectively between two waves polarized in planes at right angles to one another. A combination of these sections may be used to control, continuously, the phase of the

output wave, relative to the input, with substantially 100 per cent transmission. Application to the design of a naval Multiple Unit Steerable Antenna (MUSA: 3677 of 1937) is described. Methods for producing the differential phase-shift sections are (a) distortion of a circular guide to oval cross section, (b) insertion of diametrically opposed fins inside a circular guide,(c) insertion of a dielectric plate along the guide, and (d) use of lumped-element sections of guide. A mathematical analysis of the phase changer is given in an appendix.

621.392.1:621.3.012.2 1256
Transmission Line Calculations—G. Cioni. (*Wireless Eng.*, vol. 25, p. 64; February, 1948.) Comment on 337 of March (Vaughan).

621.392.41:621.315.212:621.395.822.1 1257
Calculation of Bridged-T Networks and Their Application to Crosstalk Reduction between Coaxial Pairs—Baranov. (*See* 1295.)

621.392.43 1258
Uniform and Exponential Transmission-Lines—B. Persoz. (*Radio Franç.*, pp. 7–13; December, 1947.) The properties of uniform lines, for which the characteristic impedance is constant, are reviewed and solutions of the general equations are given for exponential lines, for which the characteristic impedance is an exponential function of distance along the line. An exponential line is compared with a $\lambda/4$ uniform line for impedance transformation; the exponential line is definitely superior where a considerable frequency range is to be covered.

621.392.43 1259
The L Network as an Impedance Transformer—F. D. Wells. (*CQ*, vol. 3, pp. 38–40, 84; November, 1947.) A nonmathematical treatment for radio amateurs of the matching of feed lines to 2-, 3- and 4-element beams. The method is simple yet versatile. Values of circuit parameters are tabulated for typical practical cases.

621.392.43:621.314.2.029.56/.58 1260
Aerial Matching Unit for H.F. Reception—Bray, Eaton, and Whitehead. (*See* 1296.)

621.396.67 1261
Fundamental Limitations of Small Antennas—H. A. Wheeler. (Proc. I.R.E., vol. 35, pp. 1479–1484; December, 1947.) The significance and use of simple fundamental formulas for antennas small compared with λ. Practical examples are given.

621.396.67 1262
The Design of a Ground-Plane Antenna—G. Thompson. (*Philips Tech. Commun.* (Australia), pp. 12–16; February, 1947.) Description with design graphs and sketch, of an omnidirectional antenna consisting of a $\lambda/4$ vertical rod and four horizontal rods in the form of a cross, matched to a coaxial cable by means of a coaxial stub.

621.396.67 1263
Slot Aerials—D. A. Bell. (*Wireless World*, vol. 54, pp. 57–58; February, 1948.) Their properties are compared and contrasted with those of the conventional dipole. A slot in an infinite conducting sheet corresponds closely to a magnetic dipole in free space. The construction of slot arrays is explained and various applications are mentioned. See also 1335 of 1947 (Booker).

621.396.67 1264
On the Theory of Slot Aerials—M. L. Levin. (*Compt. Rend. Acad. Sci.* (U.R.S.S.), vol. 58, pp. 1039–1041; November 21, 1947. In Russian.) The slot antenna is regarded as a transmission line consisting of two "knife-edge" conductors, and equations are derived determining the voltage distribution along the slot.

621.396.67 1265
Slot Antennas—N. E. Lindenblad. (Proc. I.R.E., vol. 35, pp. 1472–1479; December, 1947.) The development is described of nonprotruding antennas consisting of slots, backed by resonant cavities, in the nose or wing of an aircraft. Multiple-slot antennas may be adapted for lobe switching and a mechanically simple form of nutating antenna is possible. The development of antennas for altimeter and marker purposes is traced and applications in other fields are indicated.

621.396.67 1266
Radiation from Longitudinal Slots in a Circular Cylinder—A. A. Pistol'kors. (*Zh. Tekh. Fiz.*, vol. 17, no. 3, pp. 365–376; 1947. In Russian.) A mathematical investigation of the radiation from identical longitudinal slots arbitrarily disposed on the surface of an infinitely long ideally conducting cylinder (Fig. 1), the diameter of which is comparable with λ. The field on the surface of the cylinder is represented by superimposed "surface harmonics" corresponding to the terms of a Fourier series. Methods are indicated for determining the field set up at a great distance from the cylinder by a harmonic of order p; an equation (19) for this field is derived. The field set up by a system of slots is equal to the sum (21) of the fields set up by all harmonics. An equation (24) determining the total field due to a single slot is also derived and polar diagrams are plotted. The radial component E_{pr} of the field is also found (top of p. 376). See also 1267 below.

621.396.67 1267
Radiation from Transverse Slots on the Surface of a Circular Cylinder—A. A. Pistol'kors. (*Zh. Tekh. Fiz.*, vol. 17, no. 3, pp. 377–388; 1947. In Russian.) A complementary investigation to 1266 above. Using the diffraction equation of Kirchhoff as modified by Sommerfeld, an equation (2) is obtained determining the E_z component of the electric field in terms of a derivative of Green's function. Having determined the latter function (equations 6a and 6b) for the case of a circular cylinder, a general equation (8) is derived and methods are indicated for determining other components of the electric and magnetic fields. Using these results, the components of the fields at a great distance from the cylinder are calcultaed. The discussion is illustrated by two examples for which polar diagrams are plotted.

621.396.67 1268
On the Voltage Induced in a Receiving Aerial—S. Malatesta. (*Alta Frequenza*, vol. 16, pp. 294–298; December, 1947. In Italian, with English, French, and German summaries.) The relation between the voltage and the electric and magnetic fields is specified and an expression for the voltage is derived from energy considerations, taking account of reradiation.

621.396.67 1269
The Radiation Power and Resistance of Diffraction Aerials—Ya. N. Fel'd. (*Compt. Rend. Acad. Sci.* (U.R.S.S.) vol. 56, pp. 481–484; May 11, 1947. In Russian.) Discussion of an antenna consisting of a finite closed metallic surface with an arbitrary aperture and excited from inside by a linear conductor. Equation (5) and (10) determining respectively the radiation power and resistance are derived.

621.396.67 1270
A Helical Antenna for Circular Polarization—H. A. Wheeler. (Proc. I.R.E., vol. 35, pp. 1484–1488; December, 1947.) Basically, a helical coil designed so that area/turn = pitch $\times\lambda/2\pi$. More complex types are analyzed and the methods of coupling to transmitter or receiver circuits indicated. Use for television is suggested.

621.396.67 1271
An Improvement in End-Fire Arrays—F. K. Goward. (*Jour. I.E.E.* (London), part III, vol. 94, pp. 415–418; November, 1947.) By increasing the linear phase shift per wavelength, a narrow main beam is produced. The side lobes can be reduced to less than 18 per cent field strength by suitable arrangement of a second array.

621.396.67 1272
"Cloverleaf" Antenna for F.M. Broadcasting—P. H. Smith. (Proc. I.R.E., vol. 35, pp. 1556–1563; December, 1947.) Four $\lambda/2$ curved elements are arranged in a clover-leaf pattern. They are excited from a common central coaxial feeder, and are equivalent to a horizontal loop. One end of each of the elements is connected to the central conductor while the other ends are bolted to the four posts of a lattice tower. Calculated and measured data are included; installation and characteristics are fully discussed.

621.396.67 1273
Coupling between Aerials with Direct Feed and Aerials Excited by Radiation—R. Galletti. (*Alta Frequenza*, vol. 16, pp. 238–241; October, 1947. In Italian, with English, French, and German summaries.) The amplitude and phase of the currents induced in a reflector, and also the modifications of the projector radiation impedance caused by parasitic elements, are calculated by a simple and direct method.

621.396.67:621.3.017.143 1274
Dielectric Losses in Aerials—F. X. Eder. (*Funk und Ton*, pp. 19–25; January, 1948.) Taking account of the current distribution in a vertical antenna, the dielectric loss is calculated for an antenna conductor with a cylindrical coating of material with a finite conductivity. The loss depends on the thickness of the coating and on the length l of the antenna. For the case of excitation at the foot of the antenna, the loss has a minimum value when l is an odd multiple of $\lambda/4$, and has a very large value when l is appreciably less than $\lambda/4$. The antenna efficiency obtained from the calculated antenna resistance has a maximum value for the $\lambda/4$ antenna. With decreasing antenna length, the efficiency falls off slowly at first, but then very rapidly, and for very short antennas does not exceed 10 to 30 per cent. The results of measurements carried out on ice-coated aircraft antennas are in good agreement with the theory.

621.396.67:621.317.3.029.63/.64 1275
An Automatic Polar Diagram Recorder—Beck and Tibbs. (*See* 1400).

621.396.67:629.135 1276
Measurement of Aircraft-Antenna Patterns Using Models—G. Sinclair, E. C. Jordan, and E. W. Vaughan. (Proc. I.R.E., vol. 35, pp. 1451–1462; December, 1947.) The conditions necessary for an accurate scaled-down system cannot always be satisfied and permissible approximations are considered. Practical methods of measurement and the associated equipment are described. A new method uses the energy reradiated from a receiving antenna excited by a plane wave. "The re-radiated field is distinguished from the exciting field by its modulation, which results from varying the impedance of the receiver periodically." Construction of the model antennas and methods for calibrating the patterns in absolute terms are described. The accuracy of the measurements is discussed and illustrated by typical results. Propeller modulation and other specialized problems can conveniently be studied with models. See also 2011 of 1947.

621.396.67.029.58 1277
I1RM's 10- and 20-m Rotary Beam Array—V. E. Motto. (*Tecn. Elettronica*, vol. 2, pp. 373–382; October, 1947. In Italian.) Construction details of a system with front-to-back ratio of 10.7 db on 20 m (three elements), and 12.1 db on 10 m (four elements).

621.396.67.029.58 1278
Top-Loaded Antennas—T. M. Gordon, Jr. (*Proc. Radio Club. Amer.*, vol. 24, pp. 3–6·

January, 1947.) n account of suitable arrangements for oper ion at 3 Mc. and discussion of practical tuni methods.

621.396.67.0 .62 1279
Vertically Polarized V.H.F. Antenna Design Facto: —J. P. Shanklin. (*Communications*, vol. 27, p. 14–15, 33; December, 1947.) A coaxially-.ed dipole antenna with a gain of 2.6 db, for the frequency bands 122 to 136 Mc. and 15 to 162 Mc. To cover these broad bands, the di. meter of the radiating members was incre.sed to 0.025λ. The effect on the radiation pattern of this increase was investigated with 480-Mc. models.

621.396.671.011.2 1280
On the Radiation Impedance of an Electromagnetic Dipole—J. Patry. (*Helv. Phys. Acta*, vol. 20, pp. 455–458; December 31, 1947. In French.) Summary of Swiss Phys. Soc. paper. In previous papers (1344 of 1947 and back references), an effect was neglected which may be of great importance, especially in the case of dipoles for decimeter waves. A simple approximate solution, neglecting losses, is given for two metal cylinders of given length and diameter, in line and with center feed. A detailed theoretical treatment, taking account of losses, will be given later.

621.396.671.029.64 1281
Microwave Antenna Measurements—C. C. Cutler, A. P. King, and W. E. Kock. (Proc. I.R.E., vol. 35, pp. 1462–1471; December, 1947.) Methods specially suitable for u.h.f. are discussed and include the measurement of gain, beam width, minor lobes, wide-angle radiation, mutual coupling of antennas, phase, and polarization. The requirements of an antenna testing site are considered and the components of a complete measuring equipment are described briefly.

621.396.674 1282
Equivalence between the Fields of a Magnetic Dipole and a Frame Aerial—A. Foschini. (*Alta Frequenza*, vol. 16, pp. 232–237; October, 1947. In Italian, with English, French, and German summaries.) The electro-motive field of a flat frame antenna of any shape, whose dimensions are small compared to λ, can be transformed, by means of an extension of Stokes' theorem, to correspond with that of a magnetic dipole.

621.315+621.392.029.64+621.396.67 1283
Ultrahigh Frequency Transmission and Radiation [Book Review]—N. Marchand. J. Wiley and Sons, New York, 1947, 322 pp., $4.50. (Proc. I.R.E., vol. 35, p. 1528; December, 1947.) Theory of transmission lines, antennas, and waveguides. "The point of view is somewhat more practical than that of previous authors on the same subject."

CIRCUITS AND CIRCUIT ELEMENTS

621.314.2.029.58 1284
10.7 mc. I.F. Transformers—J.C. Michalowicz. (*Radio News*, vol. 38, pp. 55, 144; December, 1947.) Primary and secondary windings, each consisting of 17 specially grouped turns of No. 28 enameled wire are wound on the same former and are inductively tuned.

621.314.3† 1285
Some Notes on the Design of Magnetic Amplifiers—A. S. Fitzgerald. (*Jour. Frank. Inst.*, vol. 244, pp. 323–362; November, 1947.) The gain of a single stage is calculated and the relationship between the load impedance and the power input level for optimum output is considered. If I_0 is the rectified output current when there is no input and I_s the rectified output current when a current i flows in the saturation winding $(I_s-I_0)/I_s$ is called the stability factor: if it is small, adjustment of the compensating current must be precise. Gain, and output at optimum input impedance, are plotted as functions of input and tabulated for three typical core materials.

Different conditions are necessary to obtain (a) maximum gain, (b) maximum sensitivity, (c) maximum power output; these objectives are discussed for the different core materials, assuming that power is supplied at 60 c.p.s. Performance of magnetic amplifiers would be improved by raising the power-supply frequency. The design of a.c. and d.c. windings, the over-all performance of multistage amplifiers and core design are discussed. See also 960 of May.

621.314.65.015.53 1286
Voltage Impulses in Rectifiers—T. Douma. (*Philips Tech. Rev.*, vol. 9, no. 5, pp. 135–146; 1947.) A detailed theoretical study of the transient phenomena, manifested in the form of voltage impulses, that can accompany the switching action of tubes in a rectifier. The possible danger of these impulses to transformer and choke coils, particularly those in the power supplies of high-power transmitters, is noted. The values that the impulses may attain in systems fed from single phase and multiphase a.c. are derived, using stated approximations and assumptions.

The influence of parasitic capacitances which form oscillatory circuits within a system is considered. Methods of reducing the danger of voltage impulses in tube rectifiers are indicated.

621.315.212:621.392.5 1287
Video Delay Lines—J. P. Blewett and J. H. Rubel. (Proc. I.R.E., vol. 35, pp. 1580–1584. December, 1947.) Continuous coaxial transmission lines are described in which the velocity of propagation is about one-thousandth of the velocity of light. These lines include a solenoidal inner conductor and an outer conductor of stranded-wire braid. Phase and amplitude distortions in such lines are discussed, and design procedures are given for lines of optimum performance under various conditions.

621.315.5.018.44+621.396.611.029.64 1288
Conductors and Circuits for U.H.F.—L. Ratheiser. (*Radio Tech.* (Vienna), vol. 23, pp. 456–458; October, 1947.) An elementary discussion of current distribution in conductors at u.h.f., together with a description of various tank circuits.

621.317.733:620.178.3 1289
Vibrometric Circuit with Inductive Bridge—G. Sacerdote. (*Alta Frequenza*, vol. 16, pp. 228–231; October, 1947. In Italian, with English, French, and German summaries.) A formula is obtained for the voltage developed across one diagonal of a bridge in which each arm is inductively coupled to the other three arms. Such arrangements have particular application to vibration pickups.

621.318.323.2:518.4 1290
Charts for the Calculation of Premagnetized Choke Coils—R. Feldtkeller. (*Funk und Ton*, pp. 227–235; November, 1947.) Charts for finding, for dynamo sheet steel IV, the size of core, width of air-gap, wire diameter and number of turns, given the d.c. magnetizing current, the required inductance and the permitted temperature rise.

621.392+621.385.1+621.396.694.012.8 1291
Circuits and Valves in Electronics: Part 2—R. Charbonnier and J. Royer. (*Télév. Franç.*, Supplement *Électronique*, pp. 36–40; December, 1947.) Discussion of principles of cathode coupling and of its use for the apparent increase of tube input impedance, apparent decrease of capacitance, increase of circuit time-constant and cathode detection. Part 1, 359 of March.

621.392 1292
Extensions of the Theory of Networks—M. Prudhon and P. M. Prache. (*Câbles and Trans.* (Paris), vol. 2, pp. 3–13; January, 1948. With English summary.) Relations are established between the impedances of the branches, the coefficients of the mesh equations and the coefficients of the nodal equations. Formulas are then derived from which the nodal equations can be obtained easily when the network includes mutual-impedance couplings. The theory is applied to (a) a transformer, and (b) a tube circuit.

621.392 1293
Theory and Applications of Analytical Signals—J. Ville. (*Câbles and Trans.* (Paris), vol. 2, pp. 61–74; January, 1948. With English summary.) A signal is represented by a 2-dimensional energy distribution in a domain defined by time and frequency axes. Operators analogous to those of quantum mechanics are used to find a suitable distribution. This leads to a definition of the instantaneous spectrum of a signal, and of the distribution of energy associated with a particular frequency. Time integration of the instantaneous spectrum gives the normal spectrum. The instantaneous frequency of a signal is defined, using the concept of the analytical signal derived from the actual signal by analytical lengthening, time being considered as a complex variable. The concepts of instantaneous frequency and instantaneous spectrum provide a firm theoretical basis for researches on frequency modulation, continuous harmonic analysis and frequency compression, and generally, for all problems where classical harmonic analysis gives a representation inconsistent with physical reality.

621.392:621.396.813:621.396.619.13 1294
The Distortion of Frequency-Modulated Waves by Transmission Networks—A. S. Gladwin. (Proc. I.R.E., vol. 35, pp. 1436–1445; December, 1947.) A general solution is obtained by direct operational methods. Numerical examples are given. For very large deviation ratios, the distortion is nonlinear and depends on the maximum frequency deviation, but for small deviation ratios, the distortion is linear and independent of the frequency deviation. When the modulating wave consists of two sine waves, intermodulation distortion takes the form of a frequency modulation of the small h.f. component by the large l.f. one. The application of negative feedback to f.m. receivers is considered.

621.392.41:621.315.212:621.395.822.1 1295
Calculation of Bridged-T Networks and Their Application to Crosstalk Reduction between Coaxial Pairs—N. Baranov. (*Câbles and Trans.* (Paris), vol. 2, pp. 75–87; January, 1948. With English summary.) A procedure analogous to the Tchebychef approximation method is used to design two bridged-T networks with a phase difference close to an assigned value within a given frequency band. Examples are given with 180° phase difference from 60 to 100 kc. Two of these networks were used to reduce cross talk on the Brive-Cahors cable.

621.392.43:621.314.2.029.56/.58 1296
Aerial Matching Unit for H.F. Reception—T. E. Bray, J. C. Eaton, and J. W. Whitehead. (*Electronic Eng.* (London), vol. 20, p. 30; January, 1948.) A toroidal transformer for matching a balanced 100-ohm circuit to a balanced 600-ohm circuit, or vice versa. For reception in the frequency range 2 to 20 Mc.

621.392.5:518.5 1297
The Miller Integrator and its Derivatives—(*Radio Franç.*, pp. 21–23; December, 1947.) A detailed discussion of the operation of the Miller circuit and of the voltage changes which occur in its various parts. Certain modifications convert the circuit into a particular type of multivibrator, the sanatron, with an extremely linear sweep. Replacement of the two tubes by a single pentode or heptode results in the

phantastron, which combines the properties of the Miller circuit and the sanatron.

621.396.611.1 1298
The Resistance-Capacitance Oscillator—P. G. M. Dawe. (*Engineering* (London), vol. 164, pp. 429–432; October 31, 1947.) Long summary of British Association paper. A theoretical treatment of the transient behavior of 3-mesh *RC* oscillators, using the Heaviside step-function method of analysis. Cases with genuine oscillation and those with overswing are discussed, and the responses to a constant rate of rise of input voltage and to an impulsive input are considered. The results are confirmed by observation at very low frequencies; both experimental and theoretical results are shown graphically.

621.396.611.1 1299
A Non-Linear Theory of *RC*-Generators—K. Theodorchik. (*Jour. Phys.* (U.S.S.R.), vol. 9, no. 4, pp. 341–345; 1945.)

621.396.611.21:549.514.51 1300
Measurement of Equivalent Parameters of Quartz Crystals by an Oscillation Method—Shembel. (*See* 1389.)

621.396.611.21.029.58 1301
V.H.F. Crystal Oscillators—G. B. Sells. (*QST*, vol. 31, pp. 44–46, 128; November, 1947.) Details of the construction and operation of experimental 30-Mc. crystal oscillators. Performance is improved by using additional inductive feedback between anode and crystal circuits.

621.396.611.3 1302
On Multi-Frequency Coupled Oscillatory Circuits—F. Kiebitz. (*Funk und Ton*, pp. 3–7 January, 1948.) In a system of two coupled oscillatory circuits, two frequencies are possible whose periods differ from those of the individual circuits. With spark excitation, both frequencies occur simultaneously, but with undamped excitation, only a single frequency is found. These effects are discussed for inductive, capacitive, and mixed coupling between the two circuits and formulas are derived for the frequencies in the different cases.

621.396.611.3.015.3 1303
On the Transient Behaviour of *RC* Couplings—R. Lemas. (*Télév. Franç.*, Supplement *Électroniques*, pp. 29–32; December, 1947.) A complete study of *RC* circuits in the transient state requires the operational calculus, but much useful information can be gained from a discussion based on simple physical principles. Such discussion shows that, in general, the *RC* circuit affects both amplitude and phase of the input components, and that its effect is different for the fundamental and for harmonics. For reasonably faithful transmission, $RC\omega$ should be large for the fundamental, but for obtaining short pulses from a square-wave input, $RC\omega$ should be small. The reaction between tubes and the *RC* link is also discussed and some practical applications are examined.

621.396.611.4 1304
Special Circuits for V.H.F.—Cavity Resonators—L. Liot. (*Télév. Franç.*, pp. 25–28; December, 1947.) A nonmathematical account of their properties, comparing them with conventional circuits. Their use in v.h.f. oscillators is discussed and various types of coupling are described.

621.396.615 1305
On the Theory of the Blocking Oscillator—K. F. Teodorchik. (*Zh. Tekh. Fiz.*, vol. 17, no. 4, pp. 435–438; 1947. In Russian.) An equation (7) determining the operation of the oscillator is derived and various characteristics are plotted. See also 977 of May (Benjamin).

621.396.615 1306
Autostabilized Oscillator—J. Dieutegard. (*Toute la Radio*, vol. 14, pp. 16–21; December, 1947.) Full circuit and construction details of an oscillator for either the 5-meter or the 1-meter band. Stabilization by reactance tube gives practical frequency constancy for 12 per cent variation of supply voltages. With a French 829B tube, the maximum anode power is 90 watts.

621.396.615 1307
The Theory of Ladder-Type *RC* Oscillators—K. F. Teodorchik. (*Zh. Tekh. Fiz.*, vol. 17, no. 4, pp. 439–442; 1947. In Russian.) Discussion of an oscillator consisting of a tube working into a chain of *RC* sections, with resistors connected in parallel. A system of equations (I) is given and formulas (9), (10), and (11) determining respectively the frequency, condition of self-excitation, and stationary amplitude are derived.

621.396.615:621.316.726.078.3 1308
The Synchronization (Pulling-In) of a Valve Oscillator by a Harmonic of the Fundamental Frequency—O. A. Tkhorzhevski and B. K. Shembel. (*Zh. Tekh. Fiz.*, vol. 17, no. 2, pp. 215–230; 1947. In Russian.) The oscillator with an external e.m.f. applied to it, is regarded as a generator of reactive power at the fundamental frequency. Using this conception, a simple equation (16) is derived determining the pulling-in range. It follows from this equation, that for relatively small values of the external e.m.f., the range is proportional to this e.m.f., to the order number of the harmonic applied and to the characteristic impedance of the circuit. Under conditions of overloading, the range is independent of the attenuation of the circuit. The main principles of the design of feedback synchronized oscillators are discussed; experimental results fully confirm the theory.

621.396.615:621.316.726.078.3 1309
Synchronization of Oscillators—R. D. Huntoon and A. Weiss. (Proc. I.R.E., vol. 35, pp. 1415–1423; December, 1947.) An analysis of the behavior of a self-limiting oscillator based on an extension of Adler's differential equation (2522 of 1946) and similar to the paper noted in 3467 of 1947.

621.396.615:621.317.79 1310
Improved Wide-Band Wobbulator—C. P. Smith. (*Tele-Tech*, vol. 6, pp. 42–45; November, 1947.) This uses the beat frequency between a fixed-frequency klystron and a klystron whose frequency is varied mechanically. A bandwidth up to 160 Mc. can be used in the range 1 to 350 Mc. The fixed-frequency klystron is modulated by a 125-kc. square wave. Circuit diagrams are given and the merits of the system are discussed.

621.396.615.14:621.316.726.078.3 1311
Frequency Stabilization of Microwave Oscillators—R. V. Pound. (Proc. I.R.E., vol. 35, pp. 1405–1415; December, 1947.) See 1690 of 1947 for similar discussion.

621.396.622.71 1312
Improved Type of Ratio Detector—Hayes. (*See* 1476).

621.396.645 1313
Calculation of Class-C Amplifiers—G. Gaiani. (*Tecn. Elettronica*, vol. 2, pp. 233–242; September, 1947. In Italian.) An exposition of a "method of exact calculation," based on the anode characteristic curves for the tube used, and an "approximate method," using an *abac*. Both are illustrated by reference to the 834 transmitting tube.

621.396.645 1314
More Signal—Less Noise!—C. F. Bane. (*CQ*, vol. 3, pp. 13–14, 83; December, 1947.) A detailed description of a double-tuned r.f. preamplifier unit incorporating a split input coupling coil to neutralize capacitive coupling, and a 6J6 twin triode cathode-coupled amplifier stage.

621.396.645:518.3 1315
Exact Design and Analysis of Double- and Triple-Tuned Band-Pass Amplifiers—M. Dishal. (Proc. I.R.E., vol. 35, pp. 1507–1510; December, 1947.) Discussion on, and corrections of, 3065 of 1947.

621.396.645:518.4 1316
Valve Operating Point with Cathode Load—E. J. Harris. (*Wireless Eng.*, vol. 25, pp. 63–64; February, 1948.) The exact operating conditions of a cathode follower with a known voltage applied to the grid can be found by a graphical method, using static anode current/anode voltage curves.

621.396.645.029.3 1317
A Flexible Decade Amplifier—D. L. Clark. (*Audio Eng.*, vol. 32, pp. 13–16, 39; January, 1948.) A laboratory test amplifier in two units. The voltage gain of each can be made equal to 100 or 10; the main unit has, in addition, a calibrated potentiometer-type attenuator. Both units have cathode-follower outputs and may be used separately or in cascade. Provision is also made for inserting an equalizer or filter between the units. Linear distortion is kept very low by using a large degree of negative feedback, and the frequency response of each unit is flat to within 1 db between 20 c.p.s. and 20 kc. The noise level finally achieved was equivalent to about 2 uv. at the input to the first unit.

621.396.645.029.3 1318
A Modern A.F. Power Amplifier System—(*Philips Tech. Commun.* (Australia), pp. 3–18; January, 1947.) A 50-watt power amplifier with constant voltage output, enabling the power taken by individual loudspeakers to be set to any value by adjusting their impedances. Optimum operating conditions are obtained by using changes in anode supply voltage to regulate the screen voltage and a.f. drive.

621.396.645.029.3:534.78 1319
Converted ART/13 Speech Amplifier with Peak Clipper and Low-Pass Filter—W. M. Scherer. (*CQ*, vol. 3, pp. 19–21, 91; December, 1947.) An a.f. amplifier suitable for a small transmitter, made from war surplus equipment.

621.396.645.029.4 1320
Signal/Noise Ratio in Auxiliary-Wave L.F. Amplifiers—U. Tiberio. (*Alta Frequenza*, vol. 16, pp. 275–293; December, 1947. In Italian, with English, French, and German summaries.) A new method of amplification is outlined in which signals are translated into phase variations, which are subsequently expanded and applied to a phase-meter. The signal versus noise ratio for such a system is calculated by application of Nyquist's formula. A 20-db improvement is to be expected compared with ordinary l.f. methods of amplification. Measurements of the dielectric constant of solutions using the new amplifiers, are discussed.

621.396.645.029.4 1321
L.F. Medium-Power Amplification—H. Gilloux. (*Radio Franç.*, pp. 17–19; January, 1948.) Study of output stages, with and without counter-reaction, shows that, in general, the use of two tubes in parallel is preferable to a push-pull arrangement, as it eliminates difficulties due to asymmetry of the tubes, whose characteristics, even if identical at the start, do not remain identical for long.

621.396.645.2 1322
The Cathode-Coupled Amplifier—K. A. Pullen, Jr. (Proc. I.R.E., vol. 35, pp. 1510–1514; December, 1947.) Discussion on 2507 of 1946.

621.396.645.2:518.4 1323
Time-Constant, Frequency, Attenuation of Coupling Circuits—(*Audio Eng.*, vol. 31, pp. 26–27; November, 1947.) Graphs showing the attenuation on a decimal or decibel scale as a

function of the product of the frequency and the time constant.

621.396.645.35 1324
D.C. Amplifier with A.C. Mains Feed—H. Etzold. (*Funk und Ton*, pp. 200–205; October, 1947.) The possibility of operating d.c. amplifiers from a.c. mains is examined and it is shown that by the use of (a) tubes with indirectly heated cathodes, and (b) suitable voltage stabilizing arrangements, amplifiers of high constancy can be constructed.

621.396.645.36 1325
Push-Pull Input Circuits: Parts 1 and 2—W. T. Cocking. (*Wireless World*, vol. 54, pp. 7–10 and 62–66; January and February, 1948.) Methods are described for obtaining, from an unbalanced voltage, the balanced voltage required for a push-pull amplifier. The essential differences between phase-reversal and phase-splitting circuits are discussed and circuits are given in which the resistance phase splitter is applied to a diode detector. The l.f. and h.f. equivalents of a tube circuit with equal anode and cathode load resistors are discussed and the degree of unbalance is calculated for a particular case. The cathode-follower type of phase-splitting circuit, which allows one input terminal to be earthed, is analyzed. The degree of unbalance in this type of circuit can be made practically negligible by proper choice of components; suitable tubes are indicated. Operating conditions are considered in detail for a typical tube—EF37.

621.396.645.37 1326
Feedback Amplifiers—D. Migneco. (*Tecn. Elettronica*, vol. 2, pp. 127–133 and 247–257; August and September, 1947. In Italian.) A simple explanation of feedback in general and of single-, 2-, and 3-stage negative feedback amplifiers in particular.

621.396.645.371 1327
Simplification of Negative Feedback Formulae—E. G. Beard. (*Philips Tech. Commun.* (Australia), pp. 25–26; September, 1946.) Feedback formulas in terms of gain in the feedback loop, with application to the cathode-follower circuit.

621.396.645.371 1328
High-Quality Amplifier Design—P. J. Baxandall. (*Wireless World*, vol. 54, pp. 2–6; January, 1948.) Design of an amplifier with a 10-watt output, an approximately flat response from 30 to 1600 c.p.s. and less than 0.1 per cent nonlinear distortion. The two 6L6G output tetrodes are fed by an anode-follower phase inverter preceded by a pentode stage. Negative feedback is applied by means of a third winding on the specially designed output transformer, details of which are given in an appendix. Tetrodes are preferred to triodes in the output stage, since they result in a more economical design of the supply unit and require less grid swing. More negative feedback is necessary with tetrodes, but this is considered an advantage, since it tends to reduce hum. Correction *ibid.*, vol. 54, p. 71; February, 1948.

621.396.645.371 1329
The Impedances in Counter-Reaction Amplifiers—P. M. Prache. (*Câbles and Trans.* (Paris), vol. 2, pp. 15–29; January, 1948. With English summary.) Counter-reaction amplifiers can be regarded as servomechanisms in which the voltage or current gain is controlled by reaction on the input power. The surplus power can either be absorbed in resistors or reflected. In the latter case, a considerable variation of the active input or output impedances occurs. This variation is a function of the "return difference," which is defined and calculated from network theory. A generalization of Thévenin's theorem enables a relation to be established between active and passive impedances. This shows that for best operation, the passive input and output impedances must be matched to those of the external lines. It is often advantageous to correct the attenuation distortion of transmission lines by the gain of input transformers. Reflections due to impedance mismatch can be brought within assigned limits by attenuation equalization.

621.396.645.371:621.396.621 1330
Selectivity by Counter-Reaction—X. de Maistre. (*Radio Franç.*, pp. 8–11; January, 1948.) Further discussion, with practical results. For earlier work see 1041 of 1947.

621.396.662 1331
Coil-Pack Modification—L. Miller. (*Wireless World*, vol. 54, pp. 59–60; February, 1948.) Two-station switch selection with variable short-wave tuning. Full circuit and component details of the modifications are given for a standard "Weymouth" 2-circuit coil pack, but the principle can be adapted for other makes.

621.396.662.2 1332
Theory and Design of Progressive and Ordinary Universal Windings—M. Kantor. (PROC. I.R.E., vol. 35, pp. 1563–1570; December, 1947.) An extension of papers by Simon (1085 of 1946 and back references) giving more accurate results. Theoretical expressions are used to replace empirical rules. The geometrical shape of the winding is discussed and formulas are derived for the rate of progression and the gear ratio. A complete analysis is given and simple practical equations are derived. The proper number of traverses per coil revolution is a function of the coefficient of friction between the surface of the coil former and the insulation of the wire. Practical coil design procedure is outlined.

621.396.662.3 1333
Normal Waves in Multipolar Ladder Filters—P. E. Krasnushkin. (*Zh. Tekh. Fiz.*, vol. 17, no. 6, pp. 705–722; 1947. In Russian.) A filter of the ladder type consisting of an infinite number of sections, each with $(N+1)$ input and $(N+1)$ output terminals, is considered (Fig. 1). If an e.m.f. with an arbitrary distribution of complex amplitudes is applied to the filter, then after a time, a system of stationary waves will be set up, with the distribution of the amplitudes at the terminals varying from section to section. The question is whether it is possible to select the initial distribution in such a way that it will be repeated without distortion in all subsequent sections. It is shown that, for a filter described by the system of equations (1), there are N different distributions and, therefore, N different normal waves which will pass through the filter without distortion. The effects of the parameters of the section on the behavior of normal waves are then investigated and a number of interesting properties are established, such as the change from continuous to damped waves when the frequency is lowered.

621.396.662.3:518.4 1334
Charts for the Calculation of Zobel Filter Attenuations—R. Possenti. (*Alta Frequenza*, vol. 16, pp. 311–319; December, 1947. In Italian, with English, French, and German summaries.) Charts are given for calculating the losses of low-pass and high-pass Zobel filters, knowing the Q factor, the coefficient m of the derived section and the ratio of the wanted to the cutoff frequency. Previous calculation of the real and imaginary parts of the ratio of the impedances of the series and shunt arms of the various sections is not required.

621.396.662.3:518.4 1335
Graphical Aid for Frequency Selectivity Calculations—R. M. Maiden. (*Tele-Tech*, vol. 7, pp. 54–55; January, 1948.) Abac for tuned-circuit and low- and high-pass network calculations.

621.396.662.32:534.78 1336
Audio Filters for the Speech Amplifier—J. L. Galin. (*QST*, vol. 31, pp. 17–20; November, 1947.) Design considerations for shunt M-derived low-pass filters, and construction details using standard components. These filters are required for reducing the sidebands of a radiotelephone transmitter whether speech clipping is or is not used. See also 1981 of 1947 (Smith).

621.396.662.34:518.4 1337
Mathematical and Graphical Representation of 2-Circuit Broadcast Band-Pass Filters—H. Frühauf. (*Funk und Ton*, pp. 257–267 and 312–317; November and December, 1947.) Various types of band-pass filters are considered and equations are derived in general form for 2-element filters. Families of curves are given from which the filter performance can be directly obtained. Calculations are carried out for filters with inductive coupling.

621.396.662.5:621.396.712.2 1338
Design and Use of Mixing Networks—K. C. Morrical. (*Audio Eng.*, vol. 31, pp. 11–13; November, 1947.) The requirements of program mixers for broadcasting are discussed. The values of various circuit constants are calculated for two types of mixer, with simplifying assumptions which are satisfied in most applications. It is stressed that unless the attenuator is correctly loaded, it will not introduce the loss for which it was designed. The relative merits of the two types of mixer are discussed, and various necessary precautions are mentioned.

621.396.69+621.385.1+621.396.621 1339
Miniatures in Radio—J. Slišković. (*Radio Tech.* (Vienna) vol. 23, nos. 11 and 12, pp. 549–560; 1947.) An account of recent developments of miniature tubes and circuit components, with photographs and a few details of miniature receivers developed in various countries. See also 866 of April and 1002 and 1206 of May.

621.396.69 1340
Comparative Technical Study of World-Market [radio] Components—(*Radio Tech. Dig.* (*Franç.*), vol. 2, pp. 26–56; February, 1948.) A series of articles enumerating and discussing the latest types of components available in America, Great Britain, and France. The components discussed are (a) tubes, including c.r. tubes and photo cells, (b) resistors, (c) loudspeakers, (d) electrolytic capacitors, (e) paper, mica, and ceramic capacitors, (f) variable capacitors, (g) transformers, (h) coils and cores, (i) measurement apparatus, including h.f. generators, tube voltmeters, distortion meters, and c.r.o. apparatus.

GENERAL PHYSICS

530.145.6 1341
The Interaction of Radiation and Matter—P. M. Davidson. (*Proc. Roy. Soc. A*, vol. 191, pp. 542–552; December 3, 1947.) "The theory will postulate a simple wave equation and interpretations, and will therefore . . . not be directly applicable to the world of nature. Use will thus be made of the general idea, due to Dirac, that it may be possible to specify some unnatural world which lends itself more readily to mathematical representation than does the real world, but which is nevertheless so simply related to the real world that the properties of the latter may be derived, by some simple and general rule, from those of the former. . . . In the unnatural world which will be proposed in the present paper, there are sources and sinks of matter, but light requires no representation other than the Maxwellian wave."

535.42/.43+538.566 1342
Notes on Diffraction Phenomena—P. M. Duffieux. (*Ann. Phys.* (Paris), vol. 12, pp. 95–132; January and February, 1947.) Application of the principle of the conservation of energy to the phenomena of the diffraction of light by material obstacles, shows that the principle of

Huyghens and the principle of interference cannot be correctly applied to the calculation of these phenomena. The above principles only give an equation for the propagation of energy in free space.

Comparison of the equations for the diffraction of light with those for beams of corpuscles shows that the vectorial quantities introduced in these equations are analogous to impulses.

Discussion of the experimental conditions in which diffraction or interference phenomena can be observed reveals two types of coherence. With Hertzian waves, the characteristic frequency results from the statistical concordance of a great number of elementary actions. In the case of light and of h.f. radiation, the quantum is an entity to which an absolute coherence can be attributed. Frequency is then no more than a characteristic coefficient of the photon.

537.11 1343

Faraday's Electrical Theory and Modern Physics—L. Flamm. (*Elektrotech. und Maschinenb.*, vol. 64, pp. 173–180; November and December, 1947.) A discussion of the intimate relations between the fundamental concepts of Faraday and modern field theories.

537.228.5:538.569.4.029.64 1344

Stark Effect in High Frequency Fields—C. H. Townes and F. R. Merritt. (*Phys. Rev.*, vol. 72, pp. 1266–1267; December 15, 1947.)

537.311.31.029.64 1345

The Conductivity of Metals at Microwave Frequencies—B. Serin. (*Phys. Rev.*, vol. 72, pp. 1261–1262; December 15, 1947.) At microwave frequencies, the ratio of r.f. to d.c. conductivity depends only on the ratio of electron mean free path to skin depth and falls with an increase of this quantity. The dependence of r.f. on d.c. conductivity for silver is shown for a frequency of 10^4 Mc.

537.525:538.551.25 1346

On the Vibrations of the Electronic Plasma—L. Landau. (*Jour. Phys.* (U.S.S.R.), vol. 10, no. 1, pp. 25–34; 1946.) Starting from an initial arbitrary nonequilibrium distribution, the vibrations are always damped, in which the frequency and decrement are deduced. The response to an external periodic electric field is calculated when its frequency is either far from or close to the natural frequency of the plasma. See also 2747 of 1947 (Borgnis).

537.525.5 1347

The Generation of Powerful Electric Oscillations in a Low-Pressure Discharge: Part 2—The Use of Current Interruptions in a Low-Pressure Arc for generating Undamped Electric Oscillations—V. L. Granovski and T. A. Suetin. (*Zh. Tekh. Fiz.*, vol. 17, no. 3, pp. 291–298; 1947. In Russian.) An experimental investigation was made of the appearance of oscillations in a low-pressure discharge tube with an abrupt constriction, obtained by the use of a small aperture in a diaphragm made of a dielectric material. (Details of experiments and of the tube used are given in part 1 (*ibid.*, vol. 16, p. 1023; 1946). Experiments have shown that with an aperiodic circuit, not only oscillations of the second type (with periodic interruptions of the current; see last oscillogram in Fig. 1) but also oscillations of the first type (see first oscillogram in Fig. 1) can be obtained. The amplitude, frequency, and form of the oscillations of the second type depend on the circuit used and on the conditions of the discharge. A theory of the oscillations is proposed which is confirmed satisfactorily by experiments. It is suggested that periodic interruption of the current in the tube with an abrupt constriction (stenotron) can be used for generating powerful undamped oscillations at ultrasonic frequencies. Examples of oscillation with outputs up to 1 kw. and suitable for low-voltage operation are described.

537.525.5 1348

The Effect of the Electric Circuit Parameters on Oscillations in Low-Pressure Arc Discharges—T. A. Suetin. (*Zh. Tekh. Fiz.*, vol. 17, no. 7, pp. 809–818; 1947. In Russian.) Experiments were conducted on a discharge tube with a cold mercury cathode and a hot oxide cathode (Fig. 1). The effects of the following factors on self-oscillations which may appear in the circuit were investigated: (a) parallel connection of a capacitor, (b) parallel connection of a tuned circuit, (c) changes in the operating conditions, and (d) the length of the positive column of the discharge. Several oscillograms and experimental curves are shown and the results obtained are explained.

538.213:621.318.323.2 1349

Vector Permeability—K. A. Macfadyen. (*Jour. I.E.E.* (London) part III, vol. 94, pp. 407–414; November, 1947.) A complex or vector value is assigned to the permeability, based on hysteresis and eddy-current loss considerations. Simple relations can be found between the electrical characteristics of coils and the components of the vector permeability of their cores. Results of tests on various well-known magnetic core materials are shown graphically. The optimum design for a low-loss reactor is calculated.

538.311:621.318.4 1350

Magnetic Field Configurations Due to Air Core Coils—J. P. Blewett. (*Jour. Appl. Phys.*, vol. 18, pp. 968–976; November, 1947.) An extensive table is given of the field component parallel to the axis of a circular loop of wire. The current distributions necessary to give uniform fields inside cylindrical or ellipsoidal coils are derived.

538.566+621.396.11+538.32 1351

The Field of a Plane Wave near the Surface of a Conductor—V. A. Fock. (*Bull. Acad. Sci.* (U.R.S.S.), *sér. phys.*, vol. 10, no. 2, pp. 171–186; 1946. In Russian.) The results obtained in 1412 below, concerning the distribution of currents excited by a plane wave on the surface of a body, are generalized in the following two main directions: (a) the field is determined not only on the surface of the conductor but, also at distances from it, small in comparison with the radius of curvature of the surface, and (b) the body is regarded as a good but not ideal conductor: the Leontovich conditions for the tangent components of the field are assumed valid on its surface. The method of parabolic equation (1901 of 1947) is used here. The formulas derived give a complete solution for the diffraction of a plane wave by a convex body of arbitrary shape.

538.566 1352

On the Propagation of Electromagnetic Waves along Infinite Dielectric Cylinders at Low Frequencies—B. Z. Katsenelenbaum. (*Compt. Rend. Acad. Sci.* (U.R.R.S.), vol. 58, pp. 1317–1320; December 1, 1947. In Russian.) Equations (6), determining the propagation of the waves, are derived and their solutions (10) and (11) are found.

538.569.4.029.64 1353

Microwave Spectrum Frequency Markers—R. L. Carter and W. V. Smith. (*Phys. Rev.*, vol. 72, pp. 1265–1266; December 15, 1947.) The main oscillator frequency is swept through that of the auxiliary to give a series of frequency marks. Spacings of 0.2 to 10 Mc. have been used. See also 3868 of January (Good and Coles).

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.74+551.510.535 1354

Ionosphere and Solar Research—H. v. Klüber. (*Funk und Ton*, no. 2, pp. 61–77; 1947.) A general review of present knowledge of the constitution and properties of the ionosphere and of the sun, with particular reference to the effects of solar activity on e.m. wave propagation through the ionosphere.

523.745:621.396.822.029.62 1355

Meeting of the Royal Astronomical Society [10th Oct. 1947]—(*Observatory*, vol. 67, pp. 201–210; December, 1947.) An account by Stratton of a paper by C. W. Allen entitled "Solar Radio-Noise of 200 Mc. and Its Relation to Solar Observations," and subsequent discussion. The noise is received in the spectrohelioscope hut, at Mt. Stromlo Observatory using a manually adjusted antenna having an acceptance cone of about 30°. The general character of the incident radiation and its relation to other observed solar parameters is described. No chromospheric or photospheric features appear to have an invariable physical connection or high short-period correlation with the solar noise. Flares are not generally accompanied by radio noise, but the results suggest that the early stage of a vigorous flare when bright $H\alpha$ is wide is accompanied by an outburst of radio noise. The possibility that the noise originates high in the corona is discussed.

523.75 1356

A Working Hypothesis of Solar Flares—D. S. Evans. (*Observatory*, vol. 67, pp. 218–223; December, 1947.) A comprehensive summary of the sequence of phenomena associated with flares, and discussion of a possible mechanism for reproducing many of the observed phenomena, and of observational means of checking the hypothesis. The formation in the earth's atmosphere of (a) cyclonic depressions, and (b) tornadoes and waterspouts, is considered. It is suggested that conditions in solar flares are similar to those in (b), and that material is sucked rapidly from great depths to the solar surface.

551.510.53 1357

The Stratosphere—S. Chapman. (*Weather* (London), vol. 3, pp. 2–9; January, 1948.) A general survey of present knowledge and of some of the methods by which such knowledge has been acquired.

551.510.535 1358

Researches on the Ionosphere: the Work of Sir Edward Appleton—(*Beama Jour.*, vol. 54, pp. 412–413; December, 1947.) A brief general account on the occasion of the 1947 Nobel Physics Prize award.

551.510.535:551.594.51 1359

Excitation Conditions in the Upper Atmosphere as Determined from a Study of Atomic Emission Lines in the Auroral Spectrum—W. Petrie. (*Canad. Jour. Res.*, vol. 25, pp. 293–301; September, 1947.) "Vegard's identifications of a number of lines appearing in the auroral spectrum are discussed. The conclusion is reached that a good many of these lines may be attributed to the oxygen atom in several stages of ionization. It is shown how measured line intensities and theoretical line strengths are combined to give the excitation temperature of the auroral region. Preliminary results indicate that this temperature is in the range 3000° to 60000° K. The meaning of this result is discussed briefly."

551.510.535:621.396.11 1360

Ionosphere Review: 1947—T. W. Bennington. (*Wireless World*, vol. 54, pp. 44–47; February, 1948.) An account of the changing ionospheric conditions associated with the sunspot cycle; the long-period changes in critical frequencies and sunspot numbers are shown to be closely correlated. Indications are that the sunspot maximum period occurred during the past year, and that November, 1947, was probably the month of highest m.u.f. for long-distance radio communication in the current cycle. During the winter of 1947–1948, ionospheric transmission on frequencies of 45 to 50 Mc. has frequently been possible. Maximum frequencies are expected to be slightly lower in 1948 than in 1947.

551.594.21 1361
On the Electric Field within and near Cumulus Clouds—R. Lecolazet. (*Compt. Rend. Acad. Sci.* (Paris), vol. 225, pp. 1085–1086; December 1, 1947.) Records obtained during the descent of apparatus released from an airplane. A rapid increase of the field was found below 1700 meters and a close correlation between variations of the field and passage through cumulus clouds. Maximum values of the field were found in the middle of the clouds and minimum values underneath them. An explanation is based on differences of conductivity.

551.594.21/.22 1362
Progressive Lightning: Part 7—Directly-Correlated Photographic and Electrical Studies of Lightning from Near Thunderstorms—D. J. Malan and B. F. J. Schonland. (*Proc. Roy. Soc. A*, vol. 191, pp. 485–503; December 3, 1947.) "An analysis has been made of the direct correlation of luminous and electrical field-changes produced by thirty-seven lightning discharges to ground. These discharges comprised 199 separate strokes, most of which were within a distance of 6 km." For previous parts see 436 of 1939, 424, 1317, 1781, and 3133 of 1938, and back references.

LOCATION AND AIDS TO NAVIGATION

621.396.9.029.54:551.594.6 1363
Some Directional Observations of Atmospherics on 1000 Metres during Sunset Time—S. R. Khastgir, M. K. Das Gupta, and D. K. Ganguli. (*Indian Jour. Phys.*, vol. 21, pp. 169–180; August, 1947.) The theory of sunrise maxima and minima in the number and strength of atmospherics due to ionospheric variations is considered. A method for locating thunderstorm centers producing atmospherics at sunrise or sunset, and results of observations with a c.r. direction finder are given.

621.396.933 1364
Tricon—New System for Airplane Navigation—A. Francis. (*Tele-Tech*, vol. 6, pp. 38–40, 99; November, 1947.) A new system proposed by L. Alvarez. Groups of three pulse-modulation transmitters are used. The receiver is sensitive only to a coincidence of the three pulses. A pilot can detect aircraft within 6 miles of him, and is warned by a light and a noise if another aircraft is within 6 miles at the same height. Any ground area is divided into 60 miles by 2-mile tracks. An elevation diagram of the aircraft in each track is shown on the ground by means of lamps. Distance along a track is measured by counting accurately spaced pulses on board the aircraft electronically. Track, distance, and altitude are indicated by the aircraft to the ground station by frequency-coded transmissions. At present, the system is only in the design stage; experimental work on it should begin shortly.

621.396.96+621.396.933 1365
Air-Line Radio—(*Wireless World*, vol. 54, p. 28; January, 1948.) Photograph and brief description of radio equipment installed in an aircraft of British South American Airways.

621.396.96 1366
Technique and Development of Radar: Parts 5 and 6.—Demanche. (*Onde Élec.*, vol. 27, pp. 426–434 and 473–481; November and December, 1947.) Discusses various indicating systems. Part 1 to 4, 431 of March.

621.396.96 1367
Radar in Peace—W. Nowotny. (*Radio Tech.* (Vienna), vol. 23, nos. 8 and 9, pp. 373–379; 1947.) A review of (a) the use of standard radar equipment for civil purposes, (b) the development of special equipment for civil use, and (c) navigation aids of the radar type.

621.396.96 1368
Airborne Radar Equipment Design—L. H. Lynn. (*Tele-Tech.* vol. 6, pp. 50–54; November, 1947.) The AN/APS-10 light-weight assembly is described. The main components are enclosed in an air-tight container in which the pressure is maintained a little above atmospheric pressure at sea level. 3-centimeter pulses are radiated from a 7-kw. magnetron, giving a range continuously variable from 4 to 25 nautical miles, with an additional fixed 50-mile range. The antenna assembly is stabilized gyroscopically and its angle of tilt can be varied.

621.396.96:621.396.615.142:621.396.621.54 1369
Reflex Oscillators for Radar Systems—McNally and Shepherd. (*See* 1518.)

621.396.96:621.396.932 1370
Improved Marine Radar Equipment—(*Overseas Eng.*, vol. 21, pp. 118–120; November, 1947.) Description of the "Radiolocator" general-purpose radar developed by Marconi's Wireless Telegraph Co. The transmitter and antenna are mounted as a single unit and the antenna is connected by multiple cable to the receiver. A main display unit and up to three auxiliary units may be used. The frequency range is 9425 to 9525 Mc.; the antenna rotates at 30 r.p.m., giving a horizontally polarized 2° beam. Side lobes are less than 7 per cent of the main beam.

The equipment can be used almost as far as the horizon. Small fishing vessels can be detected at 7 miles range and small buoys at 1 mile. It is suggested that buoys should be fitted with corner reflectors, to make their detection easier, especially in rough seas. The central spot in the display is so small that targets can be followed to within 50 yards of the installation in calm weather. Four range scales are provided, giving maximum ranges of 1, 3, 10, and 30 nautical miles, with an accuracy on any range of better than 1 per cent of the maximum. Total power consumption is under 5 kw.

MATERIALS AND SUBSIDIARY TECHNIQUES

533.5 1371
High Vacuum Pumps—Their History and Development: Part 1—Early Types—R. Neumann. (*Electronic Eng.* (London), vol. 20, pp. 3–8; January, 1948.)

535.37 1372
Peculiar Properties of New Alkaline Earth Phosphors, sensitive to Infra-Red Rays—V. V. Antonov-Romanovski. (*Compt. Rend. Acad. Sci.* (U.R.S.S.), vol. 58, pp. 771–774; November 11, 1947. In Russian.) It was suggested by the author in 1943 that ultra-violet light not only excites alkaline earth phosphors but also accelerates the appearance of scintillation. This accelerating effect is discussed. The relative values of the light sum for excitation by light and by heat are considered.

535.37 1373
The Luminescence of Crystalline Phosphors under Constant Excitation in the Region of the Fundamental Absorption Bands—E. I. Adirovich. (*Compt. Rend. Acad. Sci.* (U.R.S.S.), vol. 57, pp. 25–28; July 1, 1947. In Russian.)

535.37 1374
Temperature Extinction of Photoluminescence of Zinc Oxide—F. I. Vergunas and F. F. Gavrilov. (*Compt. Rend. Acad. Sci.* (U.R.S.S.), vol. 57, pp. 31–34; July 1, 1947. In Russian.) Experimental results show that a formula of the type given by Gurney and Mott (*Trans. Faraday Soc.*, vol. 35, part 1, pp. 69–73; 1939) for the number of quanta emitted per quantum absorbed is applicable to ZnO.

535.371:546.711 1375
A Spectroscopic Evidence for Activation of Fluorescence by High Valency Manganese Ions—G. Szigeti. E. Nagy, and E. Makai. (*Jour. Chem. Phys.*, vol. 15, pp. 881–882; December, 1947.) The emission spectrum curve for Mn-activated $ZnBeSiO_3$ phosphors is the same curve as that for the extinction coefficient of K_2MnO_4 in a strong alkaline solution. The fluorescence emission centers are probably associated with the $(MnO_4)^{--}$ and $(MnO_4)^-$ ions embedded in the silicate lattice.

537.311.3:621.383 1376
Conductivity of Evaporated Films of Lead Selenide—O. Simpson. (*Nature* (London), vol. 160, pp. 791–792; December 6, 1947.) Films of thickness 0.5μ on pyrex are found to be extremely sensitive to oxygen, pressure of 10^{-4} to 10^{-6} mm Hg being sufficient to cause the resistance to increase by a factor of 10 or more. A theoretical explanation of the observed effects is given.

546.287+621.315.61 1377
Silicone Insulation Board—(*Elec. Times*, vol. 113, p. 13; January 1, 1948.) Small quantities of this material are now obtainable. It is capable of continuous operation at 250°C, has low loss even at this temperature and has high mechanical and breakdown strength.

621.3(54) 1378
Electrical Engineering Problems in the Tropics: Part 1—R. Allan. (*Beama Jour.*, vol. 54, pp. 442–447; December, 1947.) Long summary of I.E.E. paper. A discussion of operating conditions for electrical equipment in India. The effects of unskilled labor, high temperature, strong sunlight, and high relative humidity are considered. In particular, at temperatures around 90°C, fibrous insulating materials can disintegrate, causing mechanical failure, and with the relative humidity at about 90 per cent at these temperatures, good insulators may become poor conductors, causing electrical failure. To be concluded.

621.314.634 1379
On Selenium Rectifiers—T. I. Moldaver. (*Bull. Acad. Sci.* (U.R.S.S.), *sér. phys.*, vol. 5, nos. 4 and 5, pp. 457–466; 1941. In Russian with English summary.) An experimental investigation was carried out with selenium rectifiers prepared by condensing selenium vapor in vacuo. The preparation of the rectifiers is described in detail and the use of Fe, Ni, Al, Cd, Cu, and Zn for contact electrodes is discussed. The use of Cd, Zn, Pb, Sn, Au, and various alloys for the preparation of emission cathodes was also investigated. A theoretical discussion of the results is given and Meyer's theory of the barrier layer is contradicted.

621.315.59+537.311.33 1380
Excess-Defect Germanium Contacts—S. Benzer. (*Phys. Rev.*, vol. 72, pp. 1267–1268; December 15, 1947.) As forecast by Sosnowski (443 of March) rectification and photoelectric effects have been found in Ge-crystal/metal-point contacts. At higher voltages and with constant illumination, marked saturation occurs in the conducting direction. A linear photosensitivity of several milliamperes per lumen of white light is obtained and varies little with voltage and temperature. Negative-resistance and self-oscillation effects are mentioned.

621.315.59 1381
Electrical Resistance of the Contact between a Semi-Conductor and a Metal—A. V. Joffe. (*Jour. Phys.* (U.S.S.R.), vol. 10, no. 1, pp. 49–60; 1946.) Measurements of contact potential showed its independence of temperature and the specific conductivity of the specimen. The dependence of the resistance near the electrodes on the potential difference, temperature, and current direction was investigated; rectification was feebly present.

621.315.61.011.5:546.431.823:536.48 1382
Dielectric Constant of Barium Titanate at Low Temperatures—B. Wul. (*Jour. Phys.* (U.S.S.R.), vol. 10, no. 1, pp. 64–66; 1946.) At 4.2°K $\epsilon=100$ and the temperature coefficient for 2 to 4.2°K is 0.005 to 0.006 degree^{-1}.

621.315.614:533.5 1383
Vacuum Drying of Paper—N. M. Foote. (*Ind. and Eng. Chem.*, vol. 39, pp. 1642–1646; December, 1947.) "The sorption of water by kraft paper and the decomposition of the paper were studied under conditions comparable to those present in impregnation processes. Decomposition accompanies severe drying and, at high temperatures, supplants the final drying." The mechanism of these processes is not fully understood.

621.315.614:621.319.4 1384
A New Kraft Capacitor Paper—H. F. Miller and R. J. Hopkins. (*Gen. Elec. Rev.*, vol. 50, pp. 20–24; December, 1947.) Discussion of modifications of the treatment of wood pulp required to improve the electrical properties of capacitor paper. The new process halves production costs, permits operation at higher temperatures and simplifies the design of capacitor housings. Paper thickness can be as low as 0.0002 inch and power factor at 100°C is lower than that obtained when linen pulp is used. A 25-kva. capacitor can now be designed for voltage ratings of upwards of 2400 volts.

621.315.616 1385
Organic H.F. Insulating Materials and Their Chemical Structure—W. M. H. Schulze. (*Funk und Ton*, pp. 295–305; December, 1947.) Study of old and new synthetic insulating materials shows the intimate relation between their molecular structure and dielectric properties. Further research should result in the discovery of a whole series of dipole-free materials with low dielectric constant and loss angle, suitable for h.f. insulation.

621.315.62+621.317.2 1386
H.F. Insulators for High Transmitting Power—W. Hüter. (*Funk und Ton*, pp. 281–294 and 8–16; December, 1947, and January, 1948.) Low dielectric loss is essential for the ceramic insulators normally used and overvoltage tests at the operating frequency are necessary. Glow and brush discharges from antenna wires, insulator terminals, tuning coils, or capacitors, can usually be avoided by suitable metallizing and by rounding off all sharp corners. A high-voltage laboratory with high-power test generators for wavelengths of 2000 meters and 600 meters is described.

621.316.54.004.5 1387
Cleaning Switch Contacts—J. J. Payne. (*Wireless World*, vol. 54, pp. 51–52; February, 1948.) The use of carbon tetrachloride, which removes grease as well as dirt, leads to excessive wear of the contacts. A better cleaning solution is 10 per cent lanolin in white spirit or trichlorethylene, which removes dirt but after evaporation leaves a film of grease on the contact surfaces.

621.383:535.215.1:546.682 1388
The Photoelectric Properties of Sulphides and Selenides of Indium—B. T. Kilomiets and S. M. Ryvkin. (*Zh. Tekh. Fiz.*, vol. 17, no. 9, pp. 987–992; 1947. In Russian.) Investigation of the photoconductive effects of treating layers of InS with sulphur vapor and of treating layers of InSe with selenium vapor. Several experimental curves are plotted and discussed.

621.396.611.21:549.514.51 1389
Measurement of Equivalent Parameters of Quartz Crystals by an Oscillation Method—B. K. Shembel. (*Zh. Tekh. Fiz.*, vol. 17, no. 3, pp. 349–364; 1947. In Russian.) With the rapidly expanding production of quartz crystals, methods for quickly checking their properties are urgently required. The properties can be investigated either by testing the crystals in the circuits for which they are intended or by measuring parameters which would give an indication of the properties of the finished product. A simple method of the latter type is described which uses auto-oscillations of the crystal in a tube oscillator circuit and differs from the direct and resonant methods based respectively on freely damped and forced oscillations. A suitable oscillatory circuit (Fig. 3) is suggested and various methods are proposed for measuring the equivalent resistance and inductance of the crystal. These tests can be carried out over the whole frequency range of quartz crystals. Special testing apparatus which does not require powerful high-stability oscillators and can be used by comparatively unskilled personnel is also discussed briefly.

628.971.6:621.327.43 1390
Fluorescent Light and Lamps—J. L. Salpeter (*Philips Tech. Commun.* (Australia), pp. 2–12; April, 1946.) Physical principles and applications.

666+621.315.612 1391
Properties and Uses of Technical Ceramics—H. Thurnauer. (*Materials and Methods*, vol. 26, pp. 87–92; December, 1947.) Discusses physical and electrical properties and tabulates data for typical materials.

MATHEMATICS

517.941.9:53 1392
The Method of the Hypercircle in Function-Space for Boundary-Value Problems—J. L. Synge. (*Proc. Roy. Soc. A*, vol. 191, pp. 447–467; December 3, 1947.) "The method has been applied to problems of the Dirichlet and Neumann types in Riemannian N-space and to elastostatic boundary value problems." The method is also applied to membrane and e.m. vibration problems. See also 2479 of 1947 (Grünberg).

518.5:621.392.5 1393
The Miller Integrator and Its Deriatives—(*See* 1297.)

501 1394
Applied Mathematics for Engineers and Physicists [Book Review]—L. A. Pipes. McGraw-Hill, London, 1946, 618 pp., 27s. 6d. (*Beama Jour.*, vol. 54, pp. 422–423; December, 1947.) Matrix algebra and the operational calculus are extensively used. The book is suitable "mostly for senior physicists and engineers with advanced mathematical proclivities, but it is also valuable as a practical guide for postgraduate workers. Without question, the book is one of the best on applied mathematics which have appeared within recent years."

512.831+512.9 1395
Matrix and Tensor Calculus [Book Review]—A. D. Machal. John Wiley and Sons, New York, 132 pp., $3.00. (*Jour. Frank. Inst.*, vol. 244, p. 412; November, 1947.) "The work is a well connected logical progression of interest to engineers generally who have need of this type of mathematics and especially to aeronautical engineers."

517.564.3(083.5) 1396
Tables of the Bessel Functions of the First Kind [Book Review]—Harvard University Press, Cambridge, Mass., and Oxford University Press, London, 1947, 55 s. each volume. (*Nature* (London), vol. 160, pp. 773–774; December 6, 1947.) Volumes 3 to 6 of the tables compiled by the staff of the Computation Laboratory, Harvard, and giving functions of the first kind of orders 1 to 9. They contain values of $J_n(x)$ for $x=0(0.001)25(0.01)99.99$. The values for $n=0, 1, 2$, and 3 are given to 18 places of decimals, while those for the higher values of n are given to 10 places. "Photographic reproduction from typescript, as used in these and other tables, has disadvantages which go some way to offset its evident advantages." For notice of Volumes 3 and 4, see 463 of March.

517.942.93 1397
Theory and Applications of Mathieu Functions [Book Review]—N. W. McLachlan. Oxford University Press, New York, 1947, 400 pp., $12.50. (Proc. I.R.E., vol. 35, p. 1528; December, 1947.) "A comprehensive reference on a useful subject" for the physicist and engineer.

MEASUREMENTS AND TEST GEAR

621.317.081.3+53.081.3 1398
Resolutions of the International Committee for Weights and Measures—Götz. (*Elektrotech. und Maschinenb.*, vol. 64, pp. 189–193; November and December, 1947.) Full text of the resolutions on changes in the electrical units. See also 2833 of 1947.

621.317.2+621.315.62 1399
H.F. Insulators for High Transmitting Power—Hüter. (*See* 1386.)

621.317.3.029.63/.64:621.396.67 1400
An Automatic Polar Diagram Recorder—A. H. Beck and S. A. Tibbs. (*Electronic Eng.*, (London), vol. 20, pp. 17–19; January, 1948.) A rapid and convenient method of plotting an independent variable against a dependent variable which can be converted into a rotation. Developed primarily to test 3-centimeter radar antennas whose beam widths were of the order of 1°, it records a complete polar diagram in 2 seconds. The record is made on Teledeltos recording paper which is drawn past a stylus by rollers geared by means of selsyns to the antenna shaft. The antenna is connected to a microwave superheterodyne receiver consisting of crystal mixer, 30-Mc. i.f. amplifier, diode second detector, and long-tailed-pair d.c. amplifier designed to work into the 5000-ohm-impedance of the recorder coil actuating the stylus. See also 1914 of 1946 and 1130 of 1947 (Clayton et al.).

621.317.32:621.396.712.2 1401
The Measurement of Circuit Voltages in a Studio Installation—de Fremery and Wenke. (*See* 1500.)

621.317.333.82 1402
The Henley 1,200,000 Volt Impulse Testing Plant. Part 4—The Complete Impulse Plant—T. R. P. Harrison. (*Distrib. Elec.*, vol. 20, pp. 303–306; January, 1948.) Discussion of its operation, with typical records from cable tests. Parts 1 to 3, 2848 of 1947 and 469 of March.

621.317.35.029.4 1403
L.F. Analyser—F. Haas. (*Toute la Radio*, vol. 14, pp. 5–7; December, 1947.) An instrument combining a l.f. oscillator with variable output voltage, a calibrated attenuator, and a simplified oscilloscope. The c.r. tube used may be either Mazda C30S, Philips DG3-1 or 913 RCA. Detailed circuit diagrams are given.

621.317.36:621.396.619.13 1404
Measurement of the Deviation Ratio in F.M.—G. V. Dlugach and I. M. Sorkin. (*Radiotekhnika* (Moscow), no. 7, pp. 25–40; 1947. In Russian.) Various methods are surveyed and formulas derived for determining errors when a frequency meter or an oscilloscope is used. The frequency detector method is also discussed. A detector similar to that proposed by Summerhayes (595 of 1943) is described briefly.

621.317.361.:621.396.611.21 1405
Frequency Calibration of Quartz Crystals—L. F. Koerner. (*Bell Lab. Rec.*, vol. 25, pp. 418–421; November, 1947.) The crystal frequency is fed to one grid of a detector tube and

a standard frequency to the other. The audio difference frequency is given by a calibrated frequency meter, and the crystal can be quickly adjusted to oscillate at the standard frequency. By this method 500 crystals can be adjusted by one operator in a day.

621.317.6:621.396.97 1406

Audio Frequency-Response Measurements in Broadcasting—A. E. Richmond. (*Audio Eng.*, vol. 32, pp. 21–24, 46; January, 1948.) Discussion of technique using a transmission measuring set.

621.317.66:621.314.2.029.3 1407

Output Transformer Efficiency—A. E. Falkus. (*Wireless World*, vol. 54, pp. 26–27; January, 1948.) A method of determining the power supplied to an audio output transformer, and its efficiency. The primary is tuned with a variable capacitance adjusted so that input current and voltage are in phase. The leakage inductance can be determined from the value of the variable capacitance.

621.317.7.029.62 1408

Measurements at Very High Frequencies—D. B. Sinclair. (*Tecn. Elettronica*, vol. 2, pp. 219–232 and 317–332; September and October, 1947. In Italian.) Fundamental principles, and discussion of tube voltmeters, crystal voltmeters, oscillators, standard signal generators, and wavemeters.

621.317.714.025.434.029.6:621.362 1409

Experiments with Thermocouple Milliammeters at Very High Radio Frequencies—G. F. Gainsborough. (*Jour. I.E.E.* (London), part III, vol. 94, pp. 427–428; November, 1947.) Discussion on 1114 of 1945.

621.317.733 1410

A New Technique in Bridge Measurements—R. Calvert. (*Electronic Eng.* (London), vol. 20, pp. 28–29; January, 1948.) An admittance bridge suitable for high frequencies may be designed by substituting a tapped transformer winding for the orthodox ratio arms. If the leakage inductance of the winding is sufficiently small, low-impedance arms can be produced such that heavy capacitive loads have virtually no effect upon their voltage ratio. Multiratio direct reading bridges covering the ranges required for antenna, h.f. cable, and transmission-line work on frequencies up to 50 Mc. have been developed and are commercially available. Experiments show that extension to 200 Mc. may be practicable. The basic circuit of such bridges is analyzed. The effects of stray capacitance and residual leakage inductance, and possible corrective measures, are discussed.

621.317.755 1411

Cathode Ray Oscillograph Recording Systems: Part 2—(*Electronic Ind.*, vol. 1, pp. 6–7; November, 1947.) Systems for doubly timed sweeps, including radar displays, superimposed patterns, scanning, spiral timebases, and double-displaced timing. Part 1, 770 of April. Part 3, 1412 below.

621.317.755 1412

Cathode Ray Oscillograph Recording Systems: Part 3—(*Electronic Ind.*, vol. 2, pp. 8–9; January, 1948.) Sweep circuits for linear and rotary displacements, velocity-controlled sweeps and circuits for (x, y) recording and for magnetic testing. Part 2, 1411 above.

621.317.79:621.396.615 1413

Improved Wide-Band Wobbulator—Smith. (*See* 1310.)

621.317.79:621.396.615 1414

Variable A. F. Portable Oscillator—A. R. A. Rendall and F. A. Peachey. (*Wireless Eng.* vol. 25, pp. 37–43; February, 1948.) The oscillator was designed for testing interstation lines used for broadcasting. The frequency ranges covered are 20 to 200, 200 to 2000, and 2000 to 20,000 c.p.s. Output is 100 milliwatts with an output impedance of 600 ohms ±3 per cent over the whole frequency range. The frequency is accurate to 1 per cent or 1 c.p.s., whichever is the greater. The output is constant to ±0.25 db, and the wave form is suitable for measuring amplitude distortion where the unwanted products are about 1 per cent.

The resistance versus temperature characteristic of a lamp is used to obtain the required negative feedback. A novel feature is provided by an increment switch, whereby the frequency can be changed by ±0.4 c.p.s. or ±0.2 c.p.s. on the lowest range, and by suitable fractions on the other ranges. See also 2644 of 1946 (Peachey, Berry, and Gunn-Russell.)

621.317.79:621.396.615:621.397.62.001.41 1415

Generator for Alignment of Television Receiver Circuits—M. Lecointe. (*Télév. Franç.*, pp. 9–13, 17; December, 1947.) Apparatus comprising (a) tuned-grid oscillator, (b) l.f. tube which passes on the modulation voltages applied to the input terminals, (c) mixing tube for modulation of the h.f. voltages, (d) two triodes used as grid detectors and serving as tube voltmeters for measurement of the injected modulation voltages and of the resulting h.f. voltages.

621.317.79:621.396.615.12 1416

New Compact Signal Generator Has Laboratory Features—G. Dexter. (*Radio News*, vol. 38, pp. 58–59, 120; December, 1947. Frequency range is 90 kc. to 210 Mc. The apparatus can be used for a.m., f.m., and television receivers. Circuit diagram and component details are given.

621.317.791:621.392.029.64 1417

Simple Measuring Equipment for Flexible Waveguides—A. M. Winchell. (*CQ*, vol. 3, pp. 28–31, 99; November, 1947.) Microwave test gear for frequency measurement, impedance matching, etc. discussed, from the point of view of a radio amateur whose previous experience has been at lower frequencies.

621.396.615.17:621.396.822:621.396.621.001.4 1418

Impulse Noise Generator for Testing F.M. Receivers—J. C. Tellier. (*Tele-Tech*, vol. 6, pp. 28–30, 98; November, 1947.) Impulse noise input to a f.m. receiver causes shock excitation of the i.f. system, which rings at its natural center frequency. Whether or not this ringing produces output from the second detector of the receiver depends upon the relative phase angle of the desired signal and the noise burst.

An external generator is here discussed, designed to simulate the desired signal and also to provide a no-noise burst having any degree of phase shift relative to the signal. Complete construction details are given. For the theory of impulse noise in f.m. receivers, see 857 of 1947 (Smith and Bradley).

621.396.621.001.4 1419

Measurements on F.M. Receivers—J. Minter. (*Proc. Radio Club Amer.*, vol. 24, pp. 6–7; January, 1947.) An outline of standard RMA test methods for f.m. receivers, described fully in RMA publication DB-2170-A: "The Measurement of Performance Characteristics of Frequency Modulated Radio Receivers."

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

531.719:621.317.73 1420

Development and Application of the Electric Expansion Meter for the Measurement of Static and Dynamic Stresses—A. R. Anderson. (*Schweiz. Arch. Angew. Wiss. Tech.*, vol. 13, pp. 321–334; November, 1947. Discussion, pp. 334–336.) A flat coil of very fine elastic resistance wire is cemented to the test-piece, whose expansion is determined from the resistance variation of the coil due to stretching. Many different applications are described. Dynamic effects are displayed on a c.r.o.

534.321.9.001.8. 1421

Testing by Ultrasonics—S. Y. White. (*Audio Eng.*, vol. 31, pp. 28–30, 40; November, 1947.) Three fundamental test methods are described: by reflection, by velocity, and by attenuation of the signal. Applications to determination of depth, submarine detection, oil prospecting, mineral exploration, flaw detection, temperature measurement, and thorough mixing of gases and liquids are discussed.

536.5.087.4:621.317.727 1422

R. F. Oscillator Controlled Potentiometer Recorder—P. Semm and R. P. Nakasone. (*Electronic Ind.*, vol. 2, pp. 6–7, 21; January, 1948.) For recording temperature variations. The fundamental measuring device is a short swing galvanometer on whose pointer is mounted a small aluminum flag. This flag moves between two coaxially mounted pancake coils, and alters the frequency of a 15-Mc. oscillator. The frequency deviation is used to drive a slide-wire contact to restore bridge balance. A feedback method of reducing hunting is described. Accuracy claimed is 0.1 per cent of full-scale range.

539.16.08 1423

Photon and Particle Counters—A. Givelet. (*Télév. Franç.*, Supplement *Électronique*, pp. 35–39; November, 1947.) A general account, with construction and working details and suggested applications.

539.16.08 1424

Resolving Power of Selfquenching Counter Tubes for High Counting Rates—E. Baldinger and P. Huber. (*Helv. Phys. Acta*, vol. 20, pp. 470–475; December 31, 1947. In German.) With constant applied voltage the dead time depends on the pulse height. Stever's method (1859 of 1942) was used to measure this dependence. From the results, the misses for high counting rates can be calculated. Measurements were also made of the dead time for different filling gases.

539.16.08 1425

Reduction of "Insensitive Time" in Geiger-Müller Counters—A. L. Hodson. (*Jour. Sci. Instr.*, vol. 25, pp. 11–13; January, 1948.) "A simple 'flip-flop' circuit has been used to reverse the voltage of a Geiger counter after each discharge, in order to reduce the insensitive time of the counter by collecting the positive ions on the wire. The new insensitive time is of the order of 3×10^{-5} sec. The circuit has been tested by measuring the inefficiency of a counter with a new, fast hard-valve anti-coincidence circuit."

620.179.16 1426

Electronic Metalloscopes—V. Parenti. (*Tecn. Elettronica*, vol. 2, pp. 353–365; October, 1947. In Italian.) An account of ultrasonic methods of detecting cracks and flaws in metals together with a detailed description of the Mark IIB detector, made by Henry Hughes and Son, London.

621.317.083.7:551.51:623.419 1427

High Altitude Research with V-2 Rockets—E. H. Krause. (*Proc. Amer. Phil. Soc.*, vol. 91, pp. 430–446; December 3, 1947.) A brief account of the equipment used, and of experiments carried out during the first year of an American investigation. The rocket can carry about 2000 pounds of instruments to a height of about 150 kilometers and, during each flight, spends 5 minutes above a height of 50 kilometers. Data acquired during the flight can be recorded directly. Records and instruments have a fair chance of surviving the impact on landing. Alternatively, the data may be communicated to the ground by a small 1000-Mc. transmitter with a peak power of 1 to 2 kilowatts. A 23-channel pulse-time-modulation system is used for conveying information and each channel is sampled 200 times per second. The present program is concerned with air pressure, temperature and composition, cosmic rays, the ionosphere, and astrophysics involving primarily the spectrum of the sun. See also 94, 3512 of 1947, and 3882 of January.

621.365 1428
A Compact 6-kW Radio Frequency Heater—(*Engineer* (London,) vol. 184, p. 537; December 5, 1947.) Brief details are given of equipment manufactured by Messrs Pye Ltd, giving a 6-kilowatt 10-Mc. output continuously variable from half to full power. A single silica tube is used as a self-excited oscillator. The equipment is self-contained, operates from a 3-phase 50-c.p.s. supply and consumes 10.5 kilowatts on full load.

621.365.5+621.365.92 1429
Industrial Applications of R. F. Heating—(*Overseas Eng.*, vol. 21, pp. 172–173; December, 1947.) New equipment for heating metallic and nonmetallic substances.

621.38.001.8:771.448.1 1430
Electronic Photoflash Unit—W. G. Many. (*Radio News*, vol. 38, pp. 44–45; December, 1947.) Circuit diagram and construction details for a semiportable unit which may be operated manually or synchronized with the camera shutter.

621.384:621.396.611.4 1431
Acceleration of Electrons by a Resonant Cavity—F. L. Hereford, Jr. (*Jour. Appl. Phys.*, vol. 18, pp. 956–960; November, 1947.) Electrons were accelerated by means of a single resonant cavity operating at λ 75 centimeters. Energies as high as 0.75 Mev. were attained by single-stage acceleration, the electrons entering the cavity virtually at zero velocity. By turning the emergent beam about and reinjecting it into the cavity in the opposite direction, 2-stage acceleration was achieved and 1.25-Mev. electrons were produced. Possibilities of a "shuttle accelerator" are discussed.

621.384.6 1432
Design of an Air Core Synchrotron—J. P. Blewett. (*Jour. Appl. Phys.*, vol. 18, pp. 976–982; November, 1947.) The theory developed in 1350 above is used to design a synchrotron in which the magnetic fields are produced by air-core coils.

621.385.833 1433
Introduction to the Electron Microscope—(*Tecn. Elettronica*, vol. 2, pp. 367–371; October, 1947. In Italian.) An elementary survey.

621.385.833 1434
On a Source of Electrons for Electron Microscopes—G. Induni. (*Helv. Phys. Acta*, vol. 20, pp. 463–467; December 31, 1947. In French.) Summary of Swiss Phys. Soc. paper. Description of a cold-cathode source giving a beam with very uniform electron velocities. The source can be used with an accelerating potential of 50 kv.

621.385.833 1435
The Use of Diaphragms in the Electron Microscope—S. G. Ellis. (*Canad. Jour. Res.*, vol. 25, pp. 322–337; November, 1947.) A method is described for deducing electron trajectories from optical measurements made on the electron microscope. A device for centering and changing apertures while the microscope is in operation is described. The choice of the size and position for diaphragms is discussed, together with other factors involved in their use.

621.385.833:621.317.729 1436
Design of Electron Lenses—R. G. E. Hutter. (*Tele-Tech*, vol. 6, p. 55; November, 1947.) The study of electron paths through electron lenses and prisms is facilitated by immersing scale models in a tank containing a low-conductivity electrolyte such as water. Equipotential lines are determined by means of probes, using a tube voltmeter as indicator.

PROPAGATION OF WAVES

538.566+535.42/.43 1437
Notes on Diffraction Phenomena—Duffieux. (*See* 1342.)

538.566+621.396.11 1438
Accurate Measurement of the Group Velocity of Radio Waves in the Atmosphere using Radar Technique—R. A. Smith, E. Franklin, and F. B. Whiting. (*Jour. I.E.E.* (London), part III, vol. 94, pp. 391–395; November, 1947. Discussion, pp. 402–406.) The time of travel of pulses between two ground stations is accurately determined in terms of calibration marks generated by an accurate crystal, account being taken of the measured delays in the receiving equipment. The mean value obtained for the velocity of propagation in the atmosphere at ground level is 299,695 ± 50 kilometers per second. This value does not differ significantly from that calculated from the best optical values for the velocity of light in free space, allowing for the refractive index of the atmosphere.

538.566+621.396.11+538.32 1439
The Field of a Plane Wave near the Surface of a Conductor—Fock. (*See* 1351.)

538.566+621.396.11 1440
A Method of determining the Velocity of Radio Waves over Land on Frequencies near 100 Kc/s—E. B. Mendoza. (*Jour. I.E.E.* (London), part III, vol. 94, pp. 396–398; November, 1947. Discussion, pp. 402–406.) The method is based on the Decca hyperbolic navigation aid system. The velocity was determined from measurements of phase in an aircraft at a point on the extension of the line joining two Decca transmitters in Belgium, knowing the radio frequency and the distance between the stations. Tests were made for dispersion, but they were negative. The average velocity was $2.9925 \pm 0.0004 \times 10^8$ meters per second; the method gives phase velocity. The low value is not inconsistent with theory.

538.566+621.396.11.029.64 1441
The Measurement of the Velocity of Propagation of Centimetre Radio Waves as a Function of Height above the Earth: Part 1—Ground-Level Measurements of the Velocity of Propagation over a Sea Path—F. E. Jones. (*Jour. I.E.E.* (London), part III, vol. 94, pp. 399–401; November, 1947. Discussion, pp. 402–406.) The radar range between accurately surveyed sites, 400 feet above sea level, was measured by means of a 9-centimeter Oboe blind-bombing system. The preparatory measurements made to assess the accuracy of the final result are discussed. All display traces were photographically recorded. The final value for the velocity is 299,687 ± 25 kilometers per second.

538.566+621.396.11]:551.510.535 1442
On the Propagation of E.M. Waves through the Upper Atmosphere—M. N. Saha, B. K. Banerjea, and U. C. Guha. (*Indian Jour. Phys.*, vol. 21, pp. 181–198; August, 1947.) A mathematical treatment taking into account the earth's magnetic field and treating the e.m. properties of the medium as tensor quantities. The equations for vertical propagation are obtained. Expressions are derived for the refractive indexes of ordinary and extraordinary waves and for the polarization and absorption of waves traveling in the ionosphere. Curves are given for the polarization ratio and refractive indexes of the two waves as functions of the magnetic latitude of the place of observation. See also 3620 of 1947 (Banerjea).

538.566:621.396.11 1443
The Field of a Microwave Dipole Antenna in the Vicinity of the Horizon: Part 2—C. L. Pekeris. (*Jour. Appl. Phys.*, vol. 18, pp. 1025–1027; November, 1947.) Extension of 224 of February to two further cases (a) when the heights of the transmitter and receiver are both less than unity (in natural units), but not zero, and (b) when the height of the transmitter is greater than unity while that of the receiver is less than unity. The results are in reasonable agreement with those of van der Pol and Bremmer (2249 of 1939).

621.396.11 1444
Solution of the Problem of Propagation of Electromagnetic Waves Along the Earth's Surface by the Methodof Parabolic Equation—M. Leontovich and V. Fock. (*Jour. Phys.* U.S.S.R.), vol. 10, no. 1, pp. 13–24; 1946.) English translation of 1901 of 1947.

621.396.11:551.510.535 1445
Ionosphere Review: 1947.—Bennington. (*See* 1360.)

621.396.11:551.510.535 1446
Long-Distance Radio Transmission—R. Lentini. (*Tecn. Elettronica*, vol. 2, pp. 285–288; September, 1947. In Italian.) A brief account of propagation conditions and m.u.f. predictions, emphasizing their interest and importance to the amateur.

621.396.11:551.510.535:523.745 1447
Sunspots and Very-High-Frequency Radio Transmission—K. A. Norton. (*QST*, vol. 31, pp. 13–17, 112; December, 1947.) Discussion of the present high solar activity and m.u.f. forecasts shows that conditions this winter are favorable for east-to-west transmission across the United States, using low power in the 50 to 54-Mc. amateur band.

621.396.11.029.4 1448
Propagation of Long Waves round the Earth—O. Zinke. (*Frequenz*, vol. 1, pp. 16–22; October, 1947.) An expression for the field strength of very long waves is derived, valid for great distances up to about 20,000 kilometers. This new equation differs in three respects from Austin's equation, (a) in dependence of field strength on distance, (b) in the effect of wavelength on attenuation, and (c) with regard to interference at the antipole of the transmitter. At great distances from the transmitter, it gives higher field strengths than Austin's equation and agrees better with experimental results.

621.396.11.029.58 1449
Operating Characteristics of the 21-Mc/s Band—O. P. Ferrell. (*CQ*, vol. 3, pp. 20–23; November, 1947.) Propagation characteristics are compared for the 10-meter, 14-meter, and 20-meter amateur bands. A polar graph is given of azimuth and skip distance for New York at various times of day for November, 1947, and the use of C.R.P.L. D-series predictors for this type of calculation is discussed. The calculation of average field strength for New York/Los Angeles transmission is also considered for November, 1947, and for the next sun spot minimum in January, 1953.

621.396.11.029.62 1450
U. S. W. Propagation—P. G. Violet. (*Funk und Ton*, nos. 2 and 4, pp. 100–105 and 206–212; 1947.) A general review of the various theories and of experimental results for short-range (<10 kilometers), medium-range (10 to 200 kilometers), and long-range (>200 kilometers) propagation in the frequency band 30 to 300 Mc.

621.396.11.029.62 1451
Any DX Today?—D. W. Heightman. (*QST*, vol. 32, pp. 25–31, 130; January, 1948.) Discussion of ionospheric propagation on frequencies near 50 Mc., with special reference to the factors affecting the m.u.f.

621.396.81.029.58 1452
More Low-Power Transmission—W. Oliver. (*Wireless World*, vol. 54, pp. 25–26; January, 1948.) Results obtained in a 5-month period of 1947 at G3XT with an input of 1 watt are compared with corresponding pre-war results (4287 of 1939.) The 1947 equipment is described briefly. Results for alternative 3-watt and 5-watt transmitters were very similar to those for the 1-watt transmitter.

621.396.812.4.029.62 1453
A Study of Tropospheric Reception at 42.8 Mc/s and Meteorological Conditions—G. W. Pickard and H. T. Stetson. (Proc. I.R.E., vol. 35, pp. 1445–1450; December, 1947.) Field strength measurements continuously recorded at a station 167 miles distant and approximately 7 miles below the line of sight from the transmitter are correlated with meteorological conditions. Analysis of results shows that propagation is entirely tropospheric. Conditions favorable to transmission are: summer, high surface refraction, rising temperatures, low wind velocities, winds parallel to the path and no frontal passages. Summary noted in 3634 of 1947.

621.396.82+621.396.11 1454
Radio Propagation in the Frequency Range 40–100 Mc/s.—Bennington. (*See* 1478.)

RECEPTION

621.396.61/.621.029.63 1455
Four-Twenty Is Fun!—Tilton. (*See* 1509.)

621.396.619.11/.14 1456
Better N.F.M. Reception with A.M. Receivers—E. Harrington and W. Bartell. (*QST*, vol. 31, pp. 38–41, 126; November, 1947.) Construction details of a simple and inexpensive narrow-band f.m. adapter for use with a.m. receivers having an i.f. of about 456 kc. A squelch circuit is used to suppress noise when the carrier is off.

621.396.62 1457
Tendencies in the Design of the Communication Type of Receiver—G. L. Crisdale and R. B. Armstrong. (*Jour. I.R.E.* (London), part III, vol. 94, pp. 418–420; November, 1947. Discussion on 223 of 1947.

621.396.621+621.396.69+621.385.1 1458
Miniatures in Radio—Slišković (*See* 1339.)

621.396.621 1459
Receiver Design—L. Ratheiser. (*Radio Tech.* (Vienna), vol. 23, pp. 475–480; October, 1947.) Discusses simple means of obtaining increased sensitivity, increase of output with parallel connection of end-stage tubes, practical limit of sensitivity increase by increase of l.f. amplification, various circuits for l.f. stages, coil design, coupling, and screening.

621.396.621 1460
On Amplitude Selectivity—Ya. I. Efrussi. (*Radiotekhnika* (Moscow), no. 7, pp. 41–56; 1947. In Russian.) Certain nonlinear systems used as amplitude limiters do not respond to the input voltage until the latter exceeds a certain minimum value; above this value, the output of the system increases linearly with the input (Fig. 2). Such a system could be used for amplifying a weak signal with a background of a stronger signal of the same frequency, since the weak signal would be, as it were, carried on the crests of the waves of the stronger signal. The author calls the system an "amplitude filter" and gives a theory of its operation. Suitable circuits are proposed and methods for designing these are discussed. Results of experiments are given and possible uses of the filter indicated.

621.396.621 1461
The Reproduction of High and Low Tones in Radio Receiving Sets—V. C. Hendriquez. (*Philips Tech. Commun.* (Australia), pp. 3–9; December, 1946.) Reprint of 751 of 1941.

621.396.621 1462
Radiomobile Model 100—(*Wireless World*, vol. 54, pp. 48–50; February, 1948.) A broadcast receiver with push-button tuning, for car use. Input is 3.25 amperes at 12 volts; output is 3.5 watts. Full circuit and component details are given.

621.396.621 1463
'Merkur W' [receiver]—V. Stuzzi. (*Radio Tech.* (Vienna), vol. 23, nos. 8 and 9, pp. 391–392; 1947.) Circuit details of an a.c. 4-stage receiver for short and medium waves, using tubes of the E21 series.

621.396.621 1464
A Receiver for the Amateur Bands—L. F. Worssam. (*R.S.G.B. Bull.*, vol. 23, pp. 130–134; January, 1948.) Circuit and construction details of an 11-tube superheterodyne receiver with good performance over the frequency range 1.7 to 60 Mc. It uses plug-in coils, and has two r.f. stages, a two-tube frequency changer, three i.f. stages at 1.6 Mc., second detector, beat-frequency oscillator, noise limiter, two a.f. stages, power supply, and a voltage stabilizer.

621.396.621:621.396.645.371 1465
Selectivity by Counter-Reaction—X. de Maistre. (*Radio Franç.*, pp. 8–11; January, 1948.) Further discussion, with practical results. For earlier work, see 1041 of 1947.

621.396.621:621.396.662 1466
Reactance Adjustment of Oscillator Coils—(*Philips Tech. Commun.* (Australia), pp. 10–13; December, 1946.) Padding errors encountered in radio receivers are shown to be mainly due to the self-capacitance of the oscillator coils. By adjusting coils so that their reactance is correct at the central tracking crossover frequency, instead of adjusting the inductance to the correct value, this trouble is eliminated.

621.396.621:621.396.662 1467
Station Selection with Frequency Modulation Receivers—E. G. Beard. (*Philips Tech. Commun.* (Australia), pp. 17–24; September, 1946.) Severe harmonic distortion and false tuning positions may be caused by the tuned circuits in f.m. receivers. The "skirts" of the resonance curves of the tuned circuits in a f.m. receiver should fall in the gaps between f.m. channels and the width of the gaps affects the least permissible Q of the tuned circuits if interference from adjacent channels is to be avoided.

621.396.621:621.396.8 1468
Sensitivity of Broadcast Receivers—A. Lennartz. (*Funk und Ton*, pp. 251–256; November, 1947.) Sensitivity is defined and its limitation by noise voltages is discussed. The design of receiver input circuits is considered with special reference to noise reduction and optimum sensitivity.

621.396.621.001.4:621.396.615.17:621.396.822 1469
Impulse Noise Generator for Testing F.M. Receivers—Tellier (*See* 1418.)

621.396.621.029.62 1470
The Varif—A New Receiver for 2 Meters—L. P. Neal and H. B. Wells. (*CQ*, vol. 3, pp. 15–19, 99; November, 1947.) A superheterodyne receiver with good sensitivity and including a noise limiter. Uniform gain is combined with continuously variable bandwidth.

621.396.621.53 1471
Broad-Band Crystal-Controlled 10-Meter Converter for the Car—N. F. Ennis. (*CQ*, vol. 3, pp. 27–29, 87; December, 1947.) A frequency-changer for tuning to 10 meters with a broadcast receiver. Stability is comparable to that of l.f. stations. Full circuit details are given.

621.396.621.54 1472
Wide-Band Superhet A.M. Turner—M. O. Kappler. (*Communications*, vol. 27, pp. 20–22, 39; December, 1947.) A receiver in which background tube noise is considerably reduced by using Ge-crystal rectifiers in a balanced bridge circuit as the mixer unit. Other features include broad-band i.f., infinite-impedance second detector, and a tuning meter arranged to show a dip in the center of the broad i.f. pass band.

621.396.621.54:518.4 1473
Abacs for the Calculation of the Oscillatory Circuits of Superheterodynes—R. Bussat. (*Radio Franç.*, pp. 14–16; December, 1947.) Since experiment is usually found necessary for checking calculations of these circuits, abacs would appear to provide the ideal method of obtaining approximate values of the circuit components. The abacs here given meet all practical requirements.

621.396.622 1474
On the Detection of U.H.F. Oscillations—E. S. Antseliovich. (*Zh. Tekh. Fiz.*, vol. 17, no. 4, pp. 443–450; 1947. In Russian.) An approximate method for designing a rectifier circuit is proposed. Parasitic capacitance is discussed in detail, and methods for reducing its effects are suggested.

621.396.622 1475
Performance Characteristics of F.M. Detector Systems—B. D. Loughlin. (*Tele-Tech*, vol. 7, pp. 30–34; January, 1948.) A detector system using a diode as a dynamic limiter, and with a variable threshold level, is described and its operation analyzed. The characteristics of other f.m. detectors, using grid-bias limiters, locked oscillators, or ratio detectors, are discussed.

621.396.622.71 1476
Improved Type of Ratio Detector—A. E. Hayes, Jr. (*Tele-Tech*, vol. 6, pp. 41, 96; November, 1947.) Discussion of a degenerative feedback circuit which secures efficient f.m. detection while maintaining satisfactory a.m. rejection. See also 3643 of 1947 (Seeley and Avins) and 248 of February.

621.396.667 1477
A Quality Switch in Lieu of a Tone Control—E. G. Beard. (*Philips Tech. Commun.* (Australia,) pp. 8–11; February, 1947.) The advantages of a quality switch as compared with a continuous tone control are discussed and details of a practical circuit are given.

621.396.82+621.396.11 1478
Radio Propagation in the Frequency Range 40–100 Mc/s.—T. W. Bennington. (*B.B.C. Quart.*, vol. 2, pp. 233–243; January, 1948.) Interference with local short-distance transmissions due to long-distance propagation of h.f. waves is discussed.

F-layer propagation will cause long-distance interference on frequencies of 40 to 50 Mc., and can take place during daylight at the equinoxes and during the winters of years near sunspot maxima, but will be very infrequent above 48 Mc. Sporadic-*E* propagation will also cause intolerable medium-distance interference during the day in summer. This will occur in the frequency range 40 to 53 Mc. but can be neglected above 53 Mc. Medium-distance interference can also be caused over the whole range of 40 to 100 Mc. by tropospheric propagation. This will be prevalent during the hours of darkness in summer, but weak and rare enough to be tolerated from transmission distances greater than a few hundred miles.

621.396.82:621.396.662.3 1479
Cavity Type Filters for Interference—D. E.

Noble. (*Tele-Tech*, vol. 7, pp. 35–37, 86; January, 1948.) Cavity filters can be effectively used by mobile radio-telephone services, operating on neighboring frequencies, to eliminate or reduce interference and so make the best use of the frequencies available. Examples show how receiver adjacent-channel selectivity is improved, and cross modulation of adjacent transmitters reduced.

621.396.822 1480
Effect of the Fluctuations [noise] and Signal Voltages on a Non-Linear System—V. Boonimovich. (*Jour. Phys.* (U.S.S.R.), vol. 10, no. 1, pp. 35–48; 1946.) A study of the analytical method using the correlation function and its relation to the intensity spectrum of the noise. The correlation functions for the noise from a simple tuned circuit, an ideal band-pass system, a Gaussian filter, and from two coupled circuits are evaluated. The effect of a nonlinear detector is treated in a general introductory manner. See also 440, 2168, and 2169 of 1945 (Rice.)

621.396.822 1481
Method for Determining Receiver Noise Figure—M. Allen. (*Tele-Tech*, vol. 7, pp. 38–39, 78; January, 1948.) The receiver output is compared with that of an ideal receiver whose output results solely from the thermal agitation noise developed across a resistance equal to the radiation resistance of the antenna. The noise factor is calculated in terms of the effective bandwidth of the receiver, its effective input resistance, and the values of receiver output without and with a known input signal. A numerical example is given for a 5-stage radar receiver.

621.396.822 1482
Noise Factor, Its Practical Calculation and Measurement—W. Daudt. (*Funk und Ton*, pp. 191–199; October, 1947.)

621.396.822 1483
Random Noise in Radio Receivers.—E. G. Beard. (*Philips Tech. Commun.* (Australia), pp. 14–22; July, 1946.) "A brief explanation of the nature of impulsive and random noise is given. The input circuits to a radio receiver are then considered from the viewpoints of gain and noise separately, and the manner of arriving at the optimum compromise is explained. Optimum signal-to-noise ratio requires a tighter coupling than optimum gain."

621.396.822:621.317.7.089.6 1484
Factors Affecting the Accuracy of Radio Noise Meters—H. E. Dinger and H. G. Paine. (Proc. I.R.E., vol. 35, pp. 1505–1507; December, 1947.) Discussion on 2227 of 1947.

621.396.822:621.385.3/.5 1485
Triode Mixer vs Pentode Amplifier.—J. Tannenbaum. (*QST*, vol. 31, pp. 30–31, 118; November, 1947.) Noise levels in triodes and pentodes are discussed. A 28-Mc. weak-signal converter is described, in which one section of a 6J6 twin triode is used as a square-law converter and the other section as an oscillator. An i.f. of 6.8 Mc. permits the converter to be coupled to most commercial receivers. Details of construction, operation, and performance are given.

621.396.822.029.62:523.745 1486
Meeting of the Royal Astronomical Society [10th Oct. 1947] (*See* 1355.)

621.396.828:621.396.622 1487
Noise Neutralizing Detector Circuit—D. L. Hings and W. W. Garstang. (*Tele-Tech*, vol. 7, pp. 40–41; January, 1948.) A sideband acceptance circuit is connected in the detector circuit so as to modulate a locally generated carrier of suitable phase and amplitude. The resultant circuit combines the incoming carrier, damaged by noise, and the local carrier, modulated by noise, in such a way that the incoming carrier is restored to its original form without the noise.

STATIONS AND COMMUNICATION SYSTEMS

621.394.441 1488
Carrier-Frequency Telegraph Systems—F. Lucantonio. (*Alta Frequenza*, vol. 16, pp. 242–265; October, 1947. In Italian, with English, French, and German summaries.) A general account of voice-frequency systems.

621.395.44 1489
The S12-102 12-Channel Carrier-Current System—M. Parmentier, J. L. Hurault, and E. Boucherot. (*Câbles and Trans.* (Paris), vol. 2, pp. 31–50; January, 1948. With English summary.) Equipment to be used as a basis for most carrier systems at present envisaged is discussed in detail. The 12 channels are included in the frequency band 60 to 108 kc. Double modulation is used. The filters have only inductance coils and capacitors. The principal applications planned or actually in service are outlined.

621.395.44:621.315.052.63 1490
The Subscriber Terminal for Rural Power-Line Carrier—L. Hochgraf. (*Bell Lab. Rec.*, vol. 25, pp. 413–417; November, 1947.) In the M1 carrier system, call signals are received as pulses which, after rectification, ring a bell. When the receiver is lifted, relays are operated to switch on the transmitter and connect it to the power line.

621.396.1 1491
How Rigid Is the Hartley Law?—(*Tele-Tech*, vol. 7, pp. 52–53; January, 1948.) An extension of the law indicates that bandwidth can be increased if signal-to-noise ratio or power is reduced, and vice versa. Discussion shows that pulse count modulation gives high transmission efficiency.

621.396.1 1492
High Frequency Allocations Revised—K. R. Boord. (*Radio News*, vol. 38, p. 132; December, 1947.) The new international radio allocations are given for h.f. broadcasting, tropical broadcasting, and amateur use. These will have effect from January 1, 1949, and will replace the regulations of the 1938 Cairo Conference. Future meetings of other international conferences on radio frequencies are also mentioned.

621.396.324 1493
Frequency-Shift Radio Teletype in World War II—R. A. Vanderlippe. (*Bell Lab. Rec.*, vol. 25, pp. 442–446; December, 1947.) Frequency-shift methods of operating radio telegraph systems reduce the effects of fading, since the carrier is radiated continuously and quick-acting automatic-volume-control can be used in the receiver. In teletypewriter systems, clear reception is important, as a lost or false pulse results in printing a wrong character. Frequency-shift systems, as used in conjunction with dual diversity reception by the American services, are discussed. See also 3702 of 1947 (Wickizer).

621.396.619.11/.13 1494
2-Channel [communication system] with F.M. and A.M.—Etzold. (*Funk und Ton*, no. 2, pp. 82–92; 1947.) An investigation of the effects of applying simultaneous f.m. and a.m. to a transmitter. An a.m. receiver was used, with rhythmic frequency sweep synchronized with the transmitter, thus providing a second channel.

621.396.619.13 1495
The Phasitron—M. Adam. (*Télév. Franç.*, pp. 20–24; November, 1947.) A detailed account of the construction and working, with an outline of its use for f.m. See also 2239 of 1947 (Adler).

621.396.619.13 1496
Frequency Modulation—E. G. Beard. (*Philips Tech. Commun.* (Australia), pp. 3–30; January, 1946.) A chapter from the author's Manual of Radio Practice (2303 of 1947.)

621.396.619.16 1497
Pulse Modulation—J. Moline. (*Radio Franç.*, pp. 3–8; January, 1948.) Definitions and a simple account of technique.

621.396.619.16:621.385.832 1498
Old and New Modulation Methods. Part 3—Pulse Modulation—W. Nowotny. (*Radio Tech.* (Vienna), vol. 23, nos. 11 and 12, pp. 511–521; 1947.) A description of single- and multichannel p.m. transmission systems. Noise limitations, bandwidth, and the various types of p.m. are discussed and an account is given of the use of the cyclophon for modulation and demodulation. See also 883 of April (Grieg, Glauber, and Moskowitz) and back reference.

621.396.619.16:621.395.43 1499
Advanced Pulse Code Modulation System—*Tele-Tech*, vol. 6, pp. 31, 103; November, 1947.) Coding is simplified by the use of an electron beam which is modulated to scan a target plate perforated so as to give "on" or "off" pulses according to the code in use. For other accounts of pulse-code modulation see 258 of February (Batcher), 545 of March (Goodall) and 818 of April.

621.396.712.2:621.317.32 1500
The Measurement of Circuit Voltages in a Studio Installation—F. de Fremery and J. W. G. Wenke. (*Philips Tech. Commun.* (Australia), pp. 3–7; February, 1947.) Translation from an article in *Philips Tech. Rev.* noted in 2722 of 1942. Describes a monitoring system for a broadcasting studio giving a meter indication of audio level with a rapid response to peaks of high level and a slower decay. A nearly linear decibel scale is obtained by using a nonlinear potential divider between the diode peak voltmeter and the d.c. amplifier. A selenium rectifier and a resistor with the same temperature coefficient are used to avoid effects due to changes of ambient temperature.

621.396.933+621.396.96 1501
Air-Line Radio—(*Wireless World*, vol. 54, p. 28; January, 1948.) Photograph and brief description of radio equipment installed in an aircraft of British South American Airways.

SUBSIDIARY APPARATUS

621.318.572:[621.395.623.8+621.396.61 1502
An Experiment in Voice Controlled Relays—L. A. Wortman. (*Radio News*, vol. 38, pp. 56–57, 162; December, 1947.) A voltage, derived from a speech-modulated input, actuates a relay switch in another circuit. A time-delay circuit prevents the relay from attempting to follow each word. Operating details and circuit diagrams are given for a loudspeaker address system and a radio-telephone transmitter.

621.396.68:621.316.722 1503
Ripple Current through Input Capacitor in Half-Wave Rectifiers—M. J. Kobilsky and J. Tepper. (*Philips Tech. Commun.* (Australia), pp. 21–24; October, 1946.) Measurements on power-supply units for a.c./d.c. receivers are described and a curve is given for accurate prediction of ripple current.

TELEVISION AND PHOTOTELEGRAPHY

06.064:621.396/.397 1504
Television Topics Dominate N.A.B. Technical Conference—(*Tele-Tech*, vol. 6, pp. 56–59, 104; November, 1947.) Report of 1947 National Association of Broadcasters' Convention. A demonstration of large-screen television projection was given. The use of empirical

formulas, recent advances in studio equipment, maintenance of transmitters and antennas, broadcasting standards, and antennas for circular polarization, were also discussed.

621.397.331.2 1505
Television Tubes by the Thousands—F. E. Butler. (*Radio News*, vol. 38, pp. 39–42, 171; December, 1947.) General description of the processes of manufacture.

621.397.331.2 1506
New Television Field-Pickup Equipment employing the Image Orthicon—J. H. Roe. (PROC. I.R.E. vol. 35, pp. 1532–1546; December, 1947.) A general description of the main units, with discussion of special features of some of the circuits used.

621.397.62.001.41:621.317.79:621.396.615 1507
Generator for Alignment of Television Receiver Circuits—Lecointe. (*See* 1415.)

TRANSMISSION

621.396.61.029.62 1508
Miniature Ten Meter Phone Transmitter—D. R. Rhodes. (*Radio News*, vol. 38, pp. 60–61, 138; December, 1947.) Conventional circuit, using miniature components, gives good signal strength. Ranges up to 3000 miles can be obtained with input power of 2 watts to the final amplifier.

621.396.61.62].029.63 1509
Four-Twenty Is Fun!—E. P. Tilton. (*QST*, vol. 31, pp. 13–16; November, 1947.) The construction of a superregenerative receiver and a simple low-power transmitter for 420 Mc. The transmitter may be built from standard components or the war-surplus equipment AN/APS-13 may be included.

VACUUM TUBES AND THERMIONICS

621.383:537.311.3 1510
Conductivity of Evaporated Films of Lead Selenide—Simpson. (*See* 1376.)

621.383:[546.86+546.36 1511
The Photoelectric Properties of Antimony-Caesium Photocells for Transmitted Light as Determined by Their Thickness—D. M. Khorosh. (*Zh. Tekh. Fiz.*, vol. 17, no. 3, pp. 341–348; 1947. In Russian.) The effect of the thickness of the antimony layer on the spectral characteristic of the photo cell was investigated experimentally. The layer thickness necessary for obtaining the maximum sensitivity was determined. The light absorption characteristics for various thicknesses of the layer are plotted.

621.385 1512
Type ECH-35 Triode Hexode—(*Philips Tech. Commun.* (Australia,) pp. 12–21; April, 1946.) Description with complete electrical data and characteristics.

621.385.1+621.392+621.396.694.012.8 1513
Circuits and Valves in Electronics: Part 2—Charbonnier and Royer. (*See* 1291.)

621.385.3/.5:621.396.822 1514
Triode Mixer *vs* Pentode Amplifier—Tannenbaum. (*See* 1485.)

621.396.615.141.2 1515
Wavelength Laws of Split-Anode Magnetrons—G. H. Metson. (*Wireless Eng.*, vol. 24, pp. 352–356; December, 1947.) The "negative resistance" mode of oscillation of a split-anode magnetron, in which the generated frequency is within wide limits independent of time of electron flight, obeys the law $\lambda = ml + c$, where l is the length of the Lecher line resonator and m and c are constants for a given magnetron. This law is reconciled with that for a resonant Lecher line, $\lambda/4 = l$, the constant $c/4$ being shown to represent a length of line which would have substantially the same equivalent capacitance as the interanode capacitance of the magnetron.

621.396.615.141.2 1516
Oscillations in a Two-Segment Magnetron Loaded with a Lecher System—S. D. Gvozdover and E. M. Moroz. (*Zh. Tekh. Fiz.*, vol. 17, no. 7, pp. 819–828; 1947. In Russian.) A Lecher system of variable length is connected to two anode segments of a magnetron (Fig. 1). Equations determining the frequency of the system (8), stationary amplitude (9), condition for self-excitation (11), and condition for stability (13) are derived. The influence of skin effect on self-excitation is discussed in detail and the stationary amplitude under various operating conditions is also examined. Curves are plotted in Figs. 3 and 4 showing, respectively, the limiting values of the operating wavelengths and of the lengths of the Lecher system. The conclusions reached agree with published experimental results.

621.396.615.141.2:533.59 1517
The Effect of the Degree of Vacuum on the Frequency of a Decimetre-Wave Magnetron Oscillator—A. P. Maydanov. (*Zh. Tekh. Fiz.*, vol. 17, no. 3, pp. 283–290; 1947. In Russian.) An experimental investigation with vacuum varying from 10^{-6} to 10^{-3} mm. Hg. A rapid and comparatively accurate method of frequency measurement was developed and a number of experimental curves are shown.

621.396.615.142:621.396.621.54:621.396.96 1518
Reflex Oscillators for Radar Systems—J. O. McNally and W. G. Shepherd. (PROC. I.R.E., vol. 35, pp. 1424–1435; December, 1947.) The requirements for beating oscillators, with descriptions of typical tubes and discussion of their characteristics. Difficulties encountered in the development and the methods of overcoming them are outlined. These included "electronic hysteresis" broad-band operation of reflex oscillators and thermal tuning of an internal cavity. Summaries noted in 1026 and 3057 of 1947.

621.396.615.142.2 1519
The Manufacture of a Reflex Klystron—D. L. Hollway. (PROC. I.R.E. (Australia), vol. 8, pp. 4–15; October, 1947.) An outline of the techniques and equipment used in Australia for the CV35. Methods are described for sealing copper disks to glass tubes by h.f. heating and for inspecting strains in glass parts by use of polarized light. Modifications of the design increased the tolerances and improved the grid-control characteristics.

621.396.822 1520
A Method for Experimental Investigation of the Statistics of Electric Fluctuations—E. J. Pumper. (*Compt. Rend. Acad. Sci.* (U.R.S.S.), vol. 53, pp. 25–27; July 10, 1946. In English.)

MISCELLANEOUS

025.45 1521
Universal Decimal Classification—An abridged English edition of the U.D.C. system will be issued as British Standard 1000A in the near future by the British Standards Institution, 24–28 Victoria Street, London, S.W.1, price 25 s. More detailed information about various sections of the U.D.C. can also be obtained from the Institution.

The classification of the vast majority of these abstracts is covered by British Standard 1000, vol. 1, part 1, vol. 2, parts 1 to 3, and vol. 4, part 2.

06.064:621.396/.397 1522
Television Topics Dominate N.A.B. Technical Conference. (*See* 1514.)

06.064 London:621.396 1523
The Amateur Radio Exhibition—(*R.S.G.B. Bull.*, vol. 23, pp. 112–115, 108; December, 1947.) A summary of Sir Stanley Angwin's opening speech and a short account of some of the exhibits. See also *Wireless World*, vol. 54, pp. 14–15; January, 1948.

621.3 General Electric 1524
The Research Laboratories of the General Electric Company—C. C. Paterson. (*Proc. Roy. Soc. A*, vol. 191, pp. 417–428; December 3, 1947.) Primarily a discussion of the way the staff of the laboratories have learned from their experience to go about their work. The need for an intimate connection between the factory and the laboratory is stressed. A brief discussion is given of a few general examples of assistance given by the laboratories.

621.396.97 1525
Broadcasting Jubilee—P. P. Eckersley. (*Wireless World*, vol. 53, pp. 454–456; December, 1947.) Genuine high-fidelity reproduction is impossible on medium and long wavelengths, and on short wavelengths using f.m., there is the disadvantage of a complicated receiver. The use of wire broadcasting is advocated and television should be developed in conjunction with the cinema.

016:6(43)+6(52) 1526
Reports on German and Japanese Industry [Book Notice]—H. M. Stationery Office, London, 1947. Classified List No. 8 (88 pp., 1 s.) deals with material published on or before May 31, 1947. Material published in June, 1947, is covered in Classified List No. 9 (8 pp., 2d.) and similar lists are available for later months.

058:621.001 1527
Industrial Research 1947 [Book Notice]—P. Dunsheath (Ed.). Todd Publishing Co., London, 1947, 534 pp. A collection, published annually, of general information, including: (a) directories of various bodies undertaking or concerned with research, both in England and overseas, (b) personnel, terms of reference, and summaries of recent reports of various officially appointed committees, (c) information about books, periodicals, libraries, films, and abstracting organizations.

62(083.74) 1528
[British Standards Institution] Yearbook—[Book Notice]—British Standards Institution, 28 Victoria Street, London, 1947, 3 s. 6 d. (*Brit. Stand. Instn. Mon. Inf. Sheet.*, p. 2; January, 1948.) Contains a numerical list of British Standards with a synopsis of each and a subject index.

621.396/.397(47) 1529
Radio Symposium [Book Notice]—Central Technical Information Bureau of the U.S.S.R. Ministry of the Communications Industry, Moscow, 184 pp. (*Radiotekhnika* (Moscow), no. 7, p. 72; 1947. In Russian.) Prepared for the Russian "Radio Day" in 1947. The book contains 18 articles on various aspects of radio broadcasting and reception, including television.

621.395 1530
Radio-Technik, Theorie und Praxis [Book Review]—J. Durrwang. Wepf and Co., Basel, fifth edition, 216 pp., 12 Swiss francs. (*Wireless Eng.*, vol. 24, p. 308; October, 1947.) A non-mathematical book intended for seriously minded amateurs and radio technicians, covering the whole field of radio from Ohm's law to radar and television.

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SECTION MEETINGS

Baltimore

"Coaxial Cable Transmission Systems," by J. A. Wood, American Telephone and Telegraph Company; March 16, 1948.

Beaumont-Port Arthur

"Radio-Frequency Heating," by R. H. Schneider, Westinghouse Electric Corporation; March 16, 1948.

Boston

"The Betatron and Synchrotron," by I. A. Getting, Massachusetts Institute of Technology; March 25, 1948.

Buffalo-Niagara

"Bessell Functions and other Screwball Concepts," by M. G. Nicholson, M. C. Scott, and R. W. Carlson, Colonial Radio Corporation; February 18, 1948.

"Pulse-Time Telemetering," by N. L. Harvey, Sylvania Electric Products Company; March 17, 1948.

Cedar Rapids

"Traveling-Wave Tubes," by J. R. Pierce, Bell Telephone Laboratories; March 26, 1948.

Cincinnati

"Magnetic Recording," by M. Camras, Armour Research Foundation; March 16, 1948.

Connecticut Valley

"Applications of Sweeping Oscillators in Test Equipment," by F. C. Marble, Kay Electric Company; April 14, 1948.

Dallas-Fort Worth

"Photoelectric Calorimeter," by P. L. Harton, Southern Methodist University; March 15, 1948.

"Peacetime Uses and Economics of Atomic Power," by P. M. Thorp, Southern Methodist University; March 15, 1948.

"Expressiveness in Engineers," by J. C. Horney, Southern Methodist University; March 15, 1948.

"Distributed Amplification," by W. R. Hewlett, Hewlett Packard Company; March 31, 1948.

Dayton

"The Univac Electronic Computer," by J. W. Mauchly, Electronic Control Company; March 11, 1948.

"Bandwidth Reduction in Communications Systems," by W. G. Tuller, Melpar, Inc.; March 31, 1948.

"R.F. Tuners for Television and F.M.," by R. Romero, Radio Corporation of America; April 8, 1948.

Detroit

"Some Equipment and Systems Aspects of Engineering Radio Communications," by L. P. Morris, Communication and Electronics Systems Division of Motorola, Inc.; March 19, 1948.

Emporium

"Printed Circuits and Miniature Electronics," by C. Brunetti, National Bureau of Standards; January 14, 1948.

Houston

"Induction and Dielectric Heating," by R. H. Schneider, Westinghouse Electric Corporation; March 15, 1948.

"Distributed Amplification," by W. R. Hewlett, Hewlett-Packard Company; April 1, 1948.

Indianapolis

"Civilian Use of Subminiature Tubes," by W. R. Jones, Sylvania Electric Products Company; February 20, 1948.

(Continued on page 36A)

SECTION MEETINGS

(Continued from page 34A)

"Components for Magnetic Recording," by T. E. Lynch, Brush Development Company; February 27, 1948.

"V.H.F. Direction Finders," by A. G. Richardson, Federal Telecommunications Laboratories; March 12, 1948.

"Avenues of Improvement in Present-Day Television," by D. G. Fink, *Electronics*; March 12, 1948.

London (Canada)

"Interference in f.m. Links," by R. W. Cooke, University of Western Ontario; March 5, 1948.

"A Vector Cardioscope," by S. Kostashuk, University of Western Ontario; March 5, 1948.

"Analysis of Wave Forms," by G. Lang, University of Western Ontario; March 5, 1948.

"Power Metering," by R. McNarry, University of Western Ontario; March 5, 1948.

"Configuration of Electrostatic Fields in Electron Lenses," by G. Harrower, University of Western Ontario; March 5, 1948.

"Frequency Allocation and Rulings Arising Out of the Atlantic City Conference," by J. C. Burbank, Royal Canadian Air Force; April 2, 1948.

Los Angeles

"A 50,000-Watt F.M. Transmitter for 100.5 Megacycles," by R. L. Norton, Eitel-McCullough, Inc.; March 16, 1948.

"Television Receiver Sound System," by A. A. Barco, RCA Industry Service Laboratory; March 16, 1948.

Louisville

"Atomic Energy, Tool or Weapon," by J. E. Reilly, Westinghouse Electric Corporation; March 12, 1948.

Milwaukee

"Understanding Twentieth Century Art," by G. B. Cumming, Milwaukee Art Institute; February 11, 1948.

"Progress in the Electric Power Rectifiers and Invertors," by W. E. Gutzwiller, Allis-Chalmers Manufacturing Company; March 10, 1948.

New York

"Metallic Dielectrics and Lenses for Microwaves," by W. E. Kock, Bell Telephone Laboratories; April 7, 1948.

Ottawa

"Electronics in Atomic Energy Research," by N. F. Moody, National Research Council; March 11, 1948.

"Tasks for the Radio Engineer for the Army in the Field," by A. E. Wrinch, Ottawa Army Headquarters; March 25, 1948.

"Development of Atomic Power," by B. R. Prentice, General Electric Company; April 6, 1948.

Philadelphia

"Microwave Spectroscopy," by D. K. Coles, Westinghouse Research Laboratories; April 1, 1948.

Portland

"Audio-Frequency Response Measurements", by A. E. Richmond, Radio Station KALE; March 31, 1948.

"A Distributed Amplifier," by A. P. Copson, Oregon State College; April 10, 1948.

"An Electronic Watch Analyzer," by J. W. Moulton, Oregon State College; April 10, 1948.

Princeton

"Radio Observations in the Field of Astronomy," by J. L. Pausey, Council for Scientific and Industrial Research (Sydney, Australia); March 4, 1948.

"High Energy Electro-Nuclear Accelerators," by M. G. White, Princeton University; April 8, 1948.

(Continued on page 38A)

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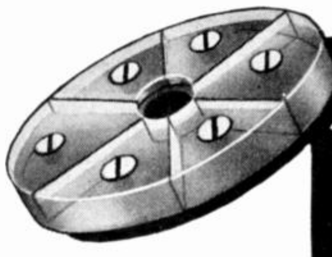

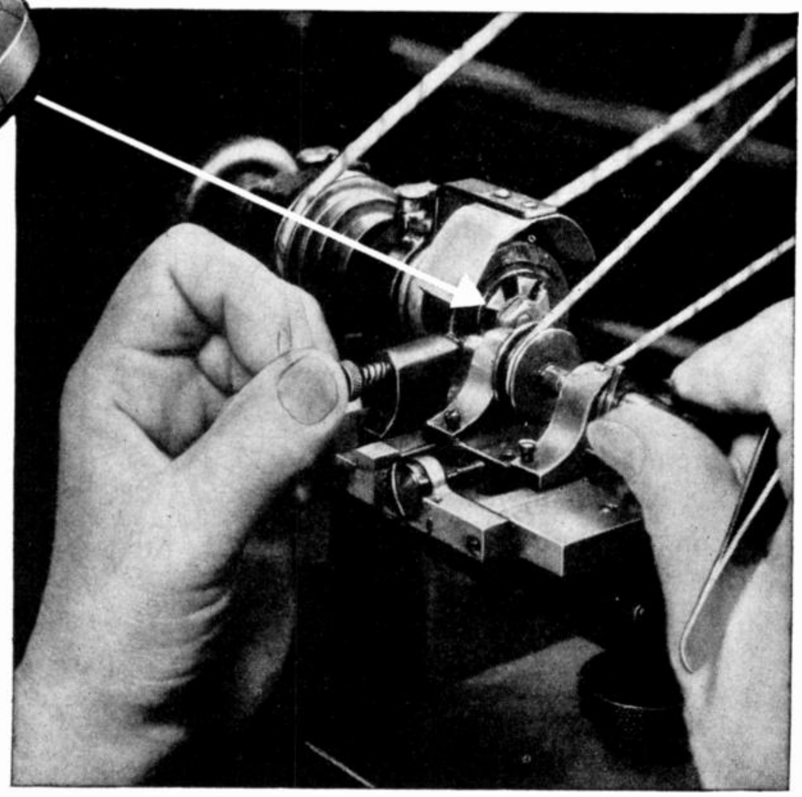

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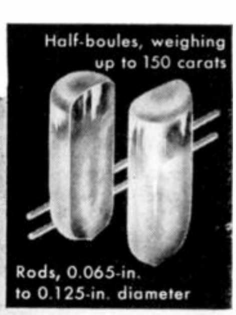

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SECTION MEETINGS

(Continued from page 36A)

Rochester

"Electronic Digital Computers," by A. W. Tyler, Eastman Kodak Company; March 18, 1948.

"Present Status of Television Broadcasting," by R. E. Shelby, National Broadcasting Companv; April 15, 1948.

Sacramento

"Latest Developments of Radar and Microwave Radio Equipment," by J. O. Perrine, American Telephone and Telegraph Company; March 31, 1948.

St. Louis

"Elements of Magnetic Recording," by C. T. Lynch, Brush Development Company; March 25, 1948.

"Safety in Aircraft Flight," by L. F. Jones, Radio Corporation of America; April 15, 1948.

San Diego

"Radar and Microwaves," by J. O. Perrine, American Telephone and Telegraph Company; March 19, 1948.

San Francisco

"Modern Interpretations of the Atom and Universe," by L. Reukema, San Francisco Section Chairman; March 10, 1948.

Seattle

"Application of Radio to Railroad Operation," by F. A. Mackenroth, Northern Pacific Railroad, and L. G. Sands, Bendix Radio Company; March 12, 1948.

Syracuse

"Selected Patents," by M. D. Norse, General Electric Company; April 1, 1948.

Toronto

"Electronics in Atomic Energy Research," by N. F. Moody, National Research Council, January 12, 1948.

"Modern Air Navigation Systems," by H. A. Ferris, Trans Canada Airlines; February 2, 1948.

"Trigger Circuits," by J. C. Gray, University of Toronto; February 23, 1948.

"Lateral Disk Recording and Reproduction," by R. E. Penton, University of Toronto; February 23, 1948.

"Volume Expansion," by C. J. Urban, University of Toronto; February 23, 1948.

"Magnetic Tape Recording," by T. E. Lynch, Brush Development Company; March 15, 1948.

Twin Cities

"Use and Control of Feedback in A.M. Transmitters," by J. C. Herber, Western Electric Company; March 4, 1948.

Williamsport

"Two Signal Performance of Some F.M. Receiver Systems," by B. D. Loughlin, Hazeltine Electronics Corporation; March 31, 1948.

SUB-SECTIONS

Akron

"Radio Telemetering Airborne Vehicles," by L. L. Rauch, Princeton University; March 25, 1948.

Fort Wayne

"Electrolytic Capacitors," by J. West, Magnavox Company; March 8, 1948.

(Continued on page 40A)

SECTION MEETINGS

(Continued from page 38A)

Hamilton

"Radio Broadcasting in Canada," by O. R. Smith, Radio Station CHML; January 26, 1948.

"Quality Control in Radio Tube Manufacturing," by A. H. Sievert, Canadian Westinghouse Electric Corporation; February 16, 1948.

"Radio Relaying," by C. Bridgland, Canadian Telegraph Company; March 8, 1948.

Long Island

"Application of High-Speed Electronic Counters," by J. J. Wild, Potter Instrument Company; March 10, 1948.

Northern New Jersey

"The Central Radio Propagation Laboratory Automatic Ionosphere Height Recorder," by C. J. Franks, C. J. Franks Laboratories; February 11, 1948.

Tour of the Federal Telecommunications Laboratories; April 14, 1948.

Toledo

"Cathode-Ray Instrument Developments," by S. Sterling, S. Sterling Company; March 29, 1948.

STUDENT BRANCH MEETINGS

Alabama Polytechnic Institute, I.R.E. Branch

"The Atomic Age—A New Challenge to Scientists and Engineers," by J. Kuderna, Alabama Polytechnic Institute; March 1, 1948.

University of Arkansas, I.R.E. Branch

"Design Considerations of a Cathode-Ray Oscilloscope," by J. A. Boatwright, Student of University of Arkansas; March 24, 1948.

Case Institute of Technology, I.R.E. Branch

"Co-Channel Interference," by R. A. Fox, Radio Station WGAR; March 24, 1948.

University of Illinois, I.R.E.—A.I.E.E. Branch

"Recent Developments in Automotive Electrical Equipment," by B. H. Short, General Motors Corporation; March 16, 1948.

Kansas State College, I.R.E.—A.I.E.E. Branch

"Magnetic Recording Illustrates Utilization of Fundamentals," by G. E. Zeigler, Midwest Research Institute; April 1, 1948.

Manhattan College, I.R.E. Branch

"Magnetic Amplifiers," by W. Dornhoefer, Ward Leonard Company; March 11, 1948.

Michigan State College, I.R.E.—A.I.E.E. Branch

"The Engineer in the Field of Management," by S. Dean, Detroit Edison Company; March 3, 1948.

University of Michigan, I.R.E.—A.I.E.E. Branch

"Design of a High-Fidelity Portable Phonograph Amplifier," by G. R. Leopold, Student; March 24, 1948.

"Developments in Man-Made Radio Interference," by R. C. Walker, Student; March 24, 1948.

STUDENT BRANCH MEETINGS

College of the City of New York, I.R.E. Branch

"Theatre Sound Systems," by R. Siegel, Altec-Lansing Corporation; March 16, 1948.

"The Present Technical Status of Television," by N. Marchand, Columbia University; March 23, 1948.

"Video Techniques," by Professor Millman, College of the City of New York; April 6, 1948.

Northwestern University, I.R.E.—A.I.E.E. Branch

"Choosing a Career in Electrical Engineering," by C. S. Mitchell, Commonwealth Edison Company; February 26, 1948.

Student Paper Competition; March 5, 1948.

Pratt Institute, I.R.E. Branch

"D.C. and A.C. Phase Inverters," by W. J. Heacock, Student; February 24, 1948.

Stanford University, I.R.E.—A.I.E.E. Branch

"Radar and Microwaves," by J. O. Perrine, American Telephone and Telegraph Company; March 29, 1948.

Syracuse University, I.R.E. Branch

"Opportunities for Engineers in the Future," by E. W. Davis, Simples Wire and Cable Company; March 18, 1948.

"Plant Construction and Operation," by B. Green, Oswego Steam Station; April 7, 1948.

The University of Texas, I.R.E.—A.I.E.E. Branch

"Some Experiments in Frictional Electricity," by W. F. Helwig, The University of Texas; March 15, 1948.

University of Utah, I.R.E.—A.I.E.E. Branch

"History and Organization of the A.I.E.E.," by J. A. McDonald, Secretary, local chapter of A.I.E.E.; March 9, 1948.

Worcester Polytechnic Institute, I.R.E.—A.I.E.E. Branch

"Opportunities that are Available for the Young Engineer Today," by E. W. Davis, Simples Wire and Cable Company; March 8, 1948.

"A Simplified Frequency Standard," by W. A. Beers, Student; April 8, 1948.

"Automatic Combustion Control," by F. Holby, Student; April 8, 1948.

"Automatic-Frequency Control for 75 WA Alternator," by O. Kennedy, Student; April 8, 1948.

"Phase Measurements by Pulse Technique," by R. Leaner, Student; April 8, 1948.

"Characteristics of D.C. Motors on Rectified A.C.," by A. Welsey and W. Wagner, Students; April 8, 1948.

"Pulse Detection," by D. Anthony, Student; April 8, 1948.

MEMBERSHIP

The following transfers and admissions were approved on May 4, 1948, to be effective June 1, 1948:

Transfer to Senior Member

Cole, L. S., 696 E. Fourth North St., Logan, Utah
Daugherty, R. M., 14433 Mark Twain Ave., Detroit, Mich.

(Continued on page 44A)

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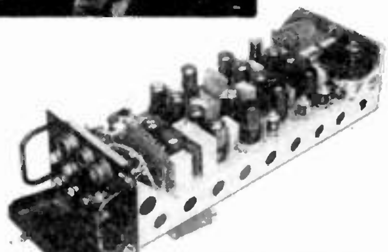
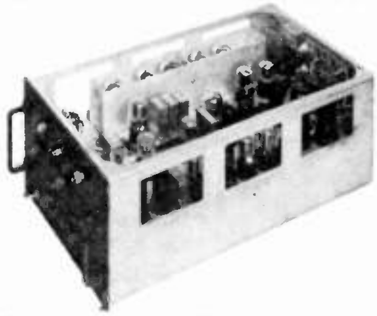
Do not fail to closely examine this list of war surplus bargains. We believe that every item listed below is a sensational value that soon can never be repeated. All equipment advertised herein is unconditionally guaranteed to the customer's satisfaction to this extent: Return any item advertised within five days after delivery for full refund except transportation charges (both ways).



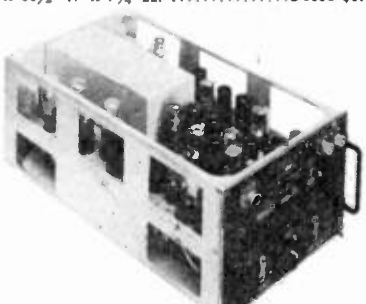
CP-11/APS-15A

Parts and tubes galore—a total of 17 tubes included, consisting of 13—6SN7GT's, 3—6SA7GT's and 1—5Y3GT. Other useful parts such as 24 V. DC motor and blower (operates on 110 V. AC), precision wire-wound 1 Meg. resistors, 80.86 Kc. crystal (1 mi. wavelength), pots, condensers, relays, etc. too numerous to mention. Weights 21 lbs. Size 22"L x 8"W x 5"H. ....**Price $9.95**



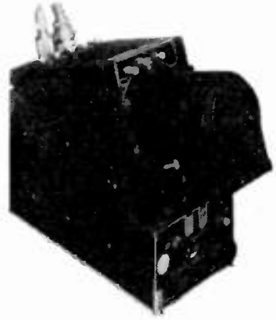
BC-1155-A SYNCHRONIZER

Another invaluable unit for the Television and VHF experimenter. Contains 19 Mc. IF strip using 5—WE717A tubes. A total of 24 tubes included, consisting of 6—WE-717A's, 2—6SL7GT's, 2—6AC7's, 5—6SN7GT's, 2—6N7GT's, 2—6L6's, 1—6V6GT, 2—6AG7's, 1—6AC7, and 1—6H6GT. Other parts included are 6 pots, 10 Amphenol 831R chassis connectors and numerous condensers, resistors, and transformers. Weight 22 lbs. Size 21"L x 11½"W x 7¾"H. ....**Price $17.75**



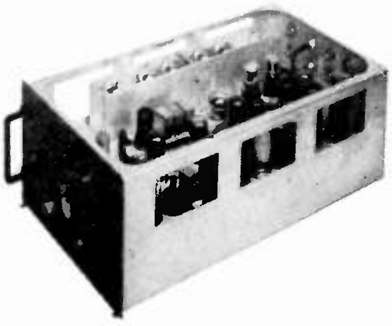
SN8/APQ-5B

Contains 31 useable tubes consisting of 2—6H6's, 3—6AC7's, 2—2050's 1—6SA7GT, 2—VR105's, 10—6AG7's, 7—6SN7GT's, 1—VR75, 2—6SL7GT's, 1—6N7. Other parts such as 17 Shallcross precision wire-wound resistors of 30,000, 120,000, 150,000, 250,000, 20,000, 200,000 and 100,000 ohms value. Relay DPDT, variable condensers, Amphenol and Cannon connectors, tap switches, networks and transformers make this another invaluable parts item at the advertised low price. Weight 28 lbs. Contained in aluminum case 17½"L x 11⅛"W x 7½"H. ....**Price $14.95**



ID-57/APQ-7 RADAR SCOPE

Contains 12 tubes: 1—5FP7, 3—6L6G's, 1—6AG7, 2—6SL7GT's, 2—6AC7's, 2—6SN7GT's, 1—6H6GT. 2 WE D168479 tube type K80 relays, magnetic yoke, pots, precision resistors, condensers, toggle switches, etc. Weight 26 lbs. Size 14"H x 20½"L x 8"W.
Price $14.95



SN-7C/APQ-13

Sensational offer for Television engineers. Contains 19 Mc. IF strip containing 5—WE717A tubes. Other HF strips containing 2—6AK5's, 3—6SL7GT's, 1—WE717A, 4—6SN7GT's, 2—6N7's, 2—6L6's, 1—6H6, 3—6AC7, 2—6AG7, 1—6V6. A total of 26 tubes. Other parts such as DPDT relay, 7 pots, 12 Amphenol 831R chassis connectors, and numerous condensers, toggle switches, RF chokes, variable condensers, and transformers. Weight approx. 25 lbs. Size 20"L x 11½"W x 7¾"H. ....**Price $19.50**

PEC-181 RECTIFIER

Input: 105-125 V. or 210-250 V. 50-60 cycle AC. Output: 7 amps. continuous at 120 V. DC. The output is effectively controlled over a range of 110-135 volts. By means of a screw-driver slot control, the rectifier may be adjusted to maintain any voltage within above range. Size 32.5"H x 20.5"W x 14.5"D. Weight 265 lbs. **$79.50**

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WESTINGHOUSE MERCURY-VAPOR

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PP-72/APQ-7

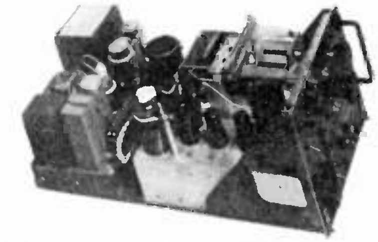
Contains 20 tubes: 6—5R4GY's, 1—6L6GT, 6—6Y6G's, 3—6SL7GT's, 2—VR105's, 2—VR150's, 1—24 V. blower and motor (may be operated on 110 V. AC 60 cycles). Numerous power resistors, HV transformers, condensers, jacks, cannon connectors, etc. Weight approx. 40 lbs. Size 25"L x 15½"W x 7¾"H, in metal case. ....**Price $19.75**

PP-2/APQ-5 POWER UNIT

400 cycle, 115 V. Contains 10 tubes as follows: 2—5U4G's, 1—6X5GT, 4—6Y6G's, 1—6SL7GT's, 2—VR150-30 and numerous condensers, transformers and resistors. Weight 17 lbs. Size 21"L x 5½"W x 7¾"H.
Price $5.75

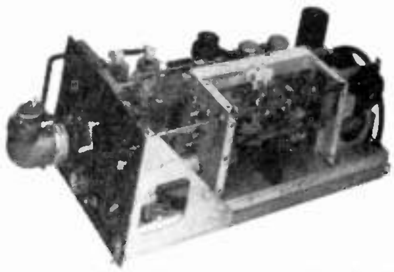
INDICATOR SCOPE ID-41/APQ-13

About 6" diameter by 15" deep. Contains 1—5FP7, 1—6AK5 tube, 5 Grain of Wheat 3 V. pilot lights, magnetic deflection yoke, condensers, potentiometers, sockets.
Price $6.95



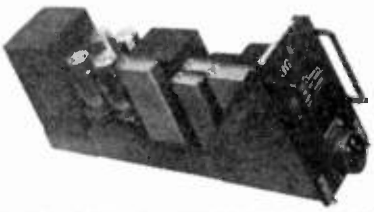
T-26/APT-2 RADAR TRANSMITTER

Contains tunable VHF curcuit using 2—JAN CTL 703A's or 368AS tubes. Other tubes are: 2—5R4GY's, 1—2X2, 1—807, 1—6AG7, 2—6AC7's, and 1—931A. Other parts such as 24 V. DC motor and blower, HV. condensers and transformers, terminal strips and Amphenol connectors, knobs, fuse holders, etc. make this unit invaluable for parts alone. Weight approx. 45 lbs. Size 21"L x 10½"W x 7¾"H, in metal case.
Price $9.75



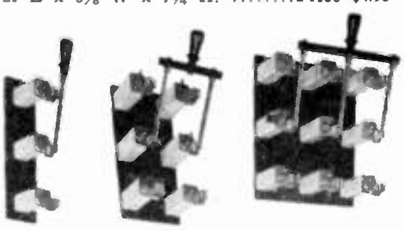
T-39/APQ-9 RADAR TRANSMITTER

Loaded with VHF parts and tubes such as 2—RCA 8012's, 1—931A, 2—807's, 1—6AG7, 2—6AC7's. The RCA 8012's are rated at 50 W. input to 500 Mc. Contains variable parallel-plate oscillator silver plated, ventilating blower and motor, ceramic tap switch, pots, terminal strips, gears, counters, etc. Weight 36 lbs. Size 22"L x 10½"W x 7¾"H.
Price $9.75



PP-51/APQ-9 RECTIFIER POWER UNIT

400 cycle 115 V. Contains 4—5R4GY, 2—4Mfd. 1000 V. DC condensers, 2—1 Mfd. 1500 V. DC condensers, 400-2600 cycle transformers, power resistors, etc. Weight 38 lbs. Size 21"L x 5⅛"W x 7¾"H. ....Price $4.95



ANTENNA KNIFE SWITCH

Has 2½" porcelain insulator bakelite base, heavy blades 4" long.
Single Pole Double Throw ....$ .75
Double Pole Double Throw 1.00
Triple Pole Double Throw 1.25

CUTLER-HAMMER SWITCH ASSEMBLY

Consists of four DPST bat-handle toggle switches, each rated at 20 amps 125 volts, with connecting straps. Price per assembly of four $1.00

HEAVY DUTY TOGGLE SWITCH

CH type C-5A DPST 20 A. 125 V. $.35

HEAVY DUTY TOGGLE SWITCH

CH type AN-3023-10 DPDT Momentary Contact 30 A. 125 V. $.35

HEAVY DUTY TOGGLE SWITCH

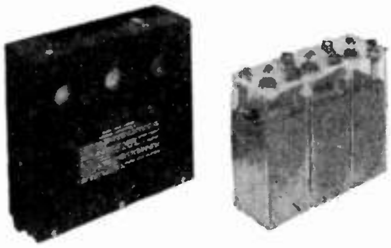
CH type C-2 DPST Center off 30 A. 125 V. $.50

HEAVY DUTY TOGGLE SWITCH

AN-3022-6B SPDT Center off 30 A. 125 V. $.25

HEAVY DUTY TOGGLE SWITCH

CH type AN3027-2B DPST 20 A. 125 V. $.25



6 V. (New) (Dry-charged) **$3.00**

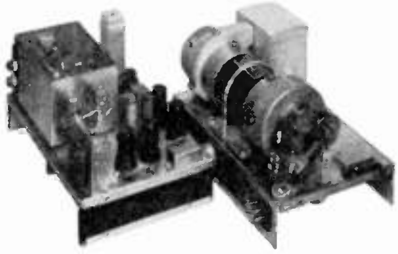
6 V. (In metal carrying case) (Add electrolyte specific gravity 1.265) (Drugstore) **$4.00**

DYNAMIC HANDMIKE

High impedance type—with press-to-talk switch that shorts microphone when released and operates a relay or other circuit when depressed. Designed for close talking PA and mobile communications service. Speech is brisk and clear. Made to stand rough handling. Black wrinkle finished. Has 6 ft. 3 conductor shielded rubber covered cable and standard amphenol plug. Made by Electro-Voice for the Signal Corps. Comparable mikes list at $28.00. Special, each $7.95

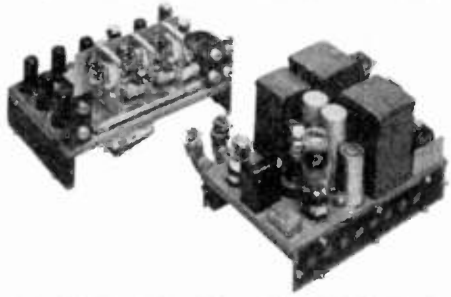
SPERRY A-5 AUTO PILOT AMPLIFER RACK

Contains 115 V. AC voltmeter and 350-450 cycle Frequency meter. A total of 4 amplifier chassis complete with following tubes included in rack: 2—1631's, 6—1632's, 3—1633's, 3—1634's, and 2—1644 tubes. Numerous transformers, resistors and condensers make this unit invaluable for parts. Weight 38 lbs. Size 12"L x 14"W x 10½"H. ....Price $6.95



TYPE CRZ-43AA AIRCRAFT RADIO RECEIVER

Another item for the VHF experimenter. Contains ten tubes: 6—SH7's, 2—6H6's, and 2—7193's. Relays, condensers, resistors, Amphenol connectors, dynamotor, carbon pile voltage regulator and numerous other parts. Weight approx. 32 lbs. Size, 12"W x 11"H x 8"D. $6.95



BC-800A RADAR TRANSMITTER & RECEIVER

Loaded with tubes and components for the VHF experimenter. Contains 19 tubes including 1—955, 3—956's, 1—2C26, 1—5U4G, 1—2X2, 1—6SN7, 7—6AC7's, 2—6SL7GT's, 1—6V6GT, and 1—6H6GT/G. Several HF tuned circuits, 7 amphenol chassis fittings, sockets, 24 V. blower and motor (will operate on 110 V. AC), 2—4Mfd. 600 V. condensers, and many other resistors and parts. Weight approx. 40 lbs. In metal case 12½"W x 11½"H x 8"D. $14.95

32 FT. MAST

And complete antenna kit. Four round wooden poles (1½" dia.) each 8 ft. long; when fitted together makes a 32 ft. mast. Can be erected to a height of 8, 16, 24 or 32 ft. Complete with guy ropes, hardware, 100 ft. PB antenna wire, 80 ft. PB ground wire, hand reel and heavy Army canvas carrying bag—suitable for use as sleeping bag. An excellent kit for field use. FM or TV antenna supports, flag, poles, etc. Our low price complete, only $18.95

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Indianapolis 4, Ind.

Unless Otherwise Stated, All of This Equipment Is Sold As Used
CASH REQUIRED WITH ALL ORDERS
Orders Shipped F.O.B. Collect

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Gould, R. V., 56 Goodrich St., Hempstead, L. I., N. Y.
Jackson, J. E., RCA Victor Company, Ltd., 1001 Lenoir St., Montreal 30, Que., Canada
Jackson, T. H., Jr., 4233 W. 61 St., Los Angeles, Calif.
Kline, M. B., 267 Santiago Ave., Rutherford, N. J.
Lafferty, J. M., General Electric Research Laboratory, Schenectady, N. Y.
Lappin, L. S., 4227 Terrace Ave., Merchantville, N. J.
Medd, J. S., Box 342, Chrsitian Ave., Stony Brook, N. Y.
Nelson, J. E., Tube Division, General Electric Company, Schenectady 5, N. Y.
Page, C. H., 11312 Old Bladensburg Rd., Silver Spring, Md.
Paschon, H. E., 726 W. Maple Ave., Merchantville, N. J.
Pierson, C. D., Jr., 1338 N. Laramie Ave., Chicago, Ill.
Potter, E. H., 213 Morgan Ave., Collingswood, N. J.
Pratt, J. H., RCA Victor Company, Ltd., 1001 Lenoir St., Montreal, Que., Canada
Randall, D. P., Box 28, University Station, Syracuse 10, N. Y.
Smith, S. R., 202 E. 52 St., Savannah, Ga.
Stearns, H. M., 319 Northern Pkwy., E. Hempstead, L. I., N. Y.
Stevens, C. A., 71 Wyman St., West Medford 55, Mass.
Stone, F. B., 330 Beechwood Ave., Haddonfield, N. J.
Terrell, J. A., 320 Belmont Ave., Haddonfield, N. J.
Turner, C. G., 106 W. 14 St., Kansas City 6, Mo.
Washburn, E. M., 6748 Rogers Ave., Merchantville, N. J.
Webber, F. G., 9 Federal Ct., Springfield 5, Mass.
Wiesner, J. B., 25 Bellevue Rd., Belmont, Mass.
Wilner, J. T., 74 Dayton St., Elizabeth 2, N. J.
Yanagisawa, S. T., Machlett Laboratories, Inc., Springdale, Conn.
Young, K. A., 43 Dwhinda Rd., Waban 68, Mass.

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Blauvelt, R. C., 510 Elmwood Rd., Bay Village, Ohio
Cooper, W. H., Box 9, R.F.D. 1, Long Branch, N. J.
D'Albora, J. B., Jr., 84 Maple Ave., Morristown, N. J.
Duke, V. J., 32 Fountain Ave., Rockville Centre, N. Y.
Glentzer, K. V., 208 W. Washington St., Chicago, Ill.
Perkins, J. R., E. I. du Pont de Nemours, 626 Schuyler Ave., Arlington, N. J.
Philpott, L. R., Finch Telecommunications, Inc., Fourth and Virginia Sts., Passaic, N. J.
Rackey, C. A., 150 Chittenden Ave., Crestwood, N. Y.
Steward, W. B., Box 2175, Houston 1, Tex.

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Austin, R. W., 1262 Lowell Rd., Schenectady 8, N. Y.
Bawden, H. G., Chatham Courts, Apt. 45, Chatham, N. J.
Blanchard, H. P., Electrical Engineering Department, Stanford University, Calif.
Buff, C., R.F.D. 2, Babylon, N. Y.
Deslkachar, P. R., 85 Livingstone St., Brooklyn 2, N. Y.
Fitzallen, J. H., 68 Brentcliffe Rd., Toronto, Leaside, Ont., Canada

(Continued on page 46A)

MEMBERSHIP

(Continued from page 44A)

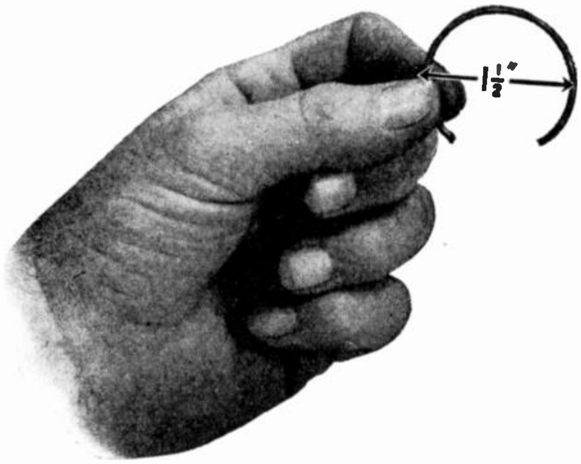
Gerry, M. E., 40-16—12 St., Long Island City, L. I., N. Y.
Hannon, S. Raytheon Manufacturing Company, Westham 54, Mass.
Helt, S., 53 W. 72 St., New York, N. Y.
Lomas, E. G., 2007 Northcliffe Ave., Montreal, Que., Canada
McClenon, D., Radio Techniques Section, Bldg. 46, Naval Research Laboratory, Washington 20, D. C.
Michael, H., 3310 Campbell Dr., New York 61, N. Y.
Matthews, L. M., Electrical Engineering Department, University of Cincinnati, Cincinnati 21, Ohio
Miller, T., 2313 Tilbury St., Pittsburgh 17, Pa.
Nadeau, A. G., 11 St. Benoit St., Quebec, Que., Canada
Premack, J., 3270 Webster Ave., Minneapolis 16, Minn.
Rao, G. V., Controller's Office of Radio Const., Willingdon Aerodrome, New Delhi, India
Sarasohn, H. M., General Headquarters, Supreme Commander for the Allied Powers, Civil Communication Section, APO 500, c/o Postmaster, San Francisco, Calif.
Schmidt, J. C., 8118 S. New Hampshire Ave., Los Angeles 44, Calif.
Schrader, W. A., c/o American Overseas Airlines, LaGuardia Field, Jackson Heights, L. I., N. Y.
Shaw, G. S., 528 W. University Ave., Gainesville, Fla.
Soler, J., Caribbean Broadcasting Corporation, WCMN, Box 755, Arecibo, P. R.
Travis, E. F., 147 Sacandaga Rd., Scotia, N. Y.
Woodcock, A. J., Box 41, Los Angeles 42, Calif.
Wyland, G. P., 1728 N. Mariposa Ave., Hollywood 27, Calif.

Admission to Member Grade

Burton, G. D., 2700 Arundel Rd., Apt. 4, Mt. Rainer, Md.
Bruce, D. C., 101 Gunterstone Rd., London W. 14, England
Conrad, T. E., Jr., 30 Hedden Pl., East Orange, N. J.
DeLiban, R., 744 Creston Rd., Berkeley 8, Calif.
Donelson, C. H., 219 Westerly Pkwy., State College, Pa.
Duncan-Smith, E., 72 Lonsdale Ave., Cosham, Portsmouth, Hants., England
Fine, R. S., Advanced Development Section, RCA Victor Division, Bldg. 5, Rm. 304, Camden, N. J.
Gardiner, C. E., 39-20—220 St., Bayside, L. I., N. Y.
Gilliland, W. D., 1448—29 Ave., Oakland 1, Calif.
Glass, A. H., 3403 Highland Ave., Kansas City, Mo.
Glaze, G. O., 4308 Halley Ter., S.E., Washington 20, D. C.
Hansen, W. O., 1333 Paul Ave., Schenectady 6, N. Y.
Harriss, J. B., 8154 Barkley Dr., Houston 17, Tex.
Jones, C. E., 206 W. Cortland St., Box 98, Croton, N. Y.
Jones, J. W., 6 Peter Cooper Rd., New York, N. Y.
Kamen, I., 200 Bennett Ave., New York 33, N. Y.
Larks, S. D., Signal Section, Headquarters Eighth Army, APO 343, c/o Postmaster, San Francisco, Calif.
Michaels, A. C., 197 Christian St., Lowell, Mass.
Moskow, H. J., 6305 N. Richmond St., Chicago 10, Ill.
Nemec, I. V., 186 Podebradska, Praha IX-Vysocany, Czechoslovakia
Rattray, A. I., 3638 N. Fremont St., Chicago 13, Ill.
Sarma, P. H. N. B., Radio Superintendent, Arthur Hope Polytechnic, Coimbatore, S. India

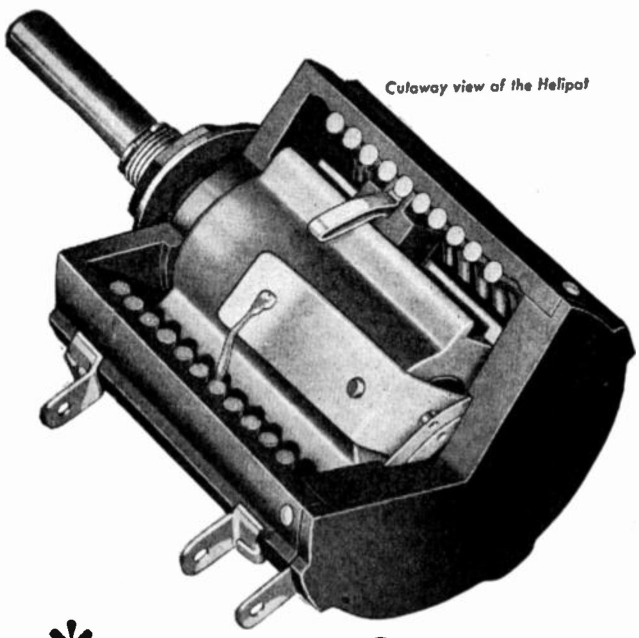
(Continued on page 48A)

Compare! Here's the Helipot Principle that is Revolutionizing Potentiometer Control in Today's Electronic Circuits



CONVENTIONAL POTENTIOMETERS have a coil diameter of approximately 1½" and provide only 4" (about 300°) of potentiometer slide wire control.

THE BECKMAN HELIPOT has the same coil diameter, yet gives up to 46" (3600°)* of potentiometer slide wire control—nearly TWELVE times as much!



Cutaway view of the Helipot

***HELIPOTS ARE AVAILABLE IN 3 STANDARD SIZES:**

TYPE A—5 watts, incorporating 10 helical turns and a slide wire length of 46 inches, case diameter 1¾", is available with resistance values from 25 ohms to 30,000 ohms.

TYPE B—10 watts, with 15 helical turns and 140" slide wire, case diameter 3¼", is available with resistance values from 100 ohms to 100,000 ohms.

TYPE C—2 watts, with 3 helical turns and 13½" slide wire, case diameter 1¾", available in resistances from 5 ohms to 10,000 ohms.

The Type B is also available in special sizes of 25 and 40 helical turns, with resistances ranging from 500 ohms to 300,000 ohms, and containing more than 100,000 change-of-resistance steps.

*Data above is for the standard Type A unit.

Some of the multiple Helipot advantages

EXTENSIVELY used on precision electronic equipment during the war, the Helipot is now being widely adopted by manufacturers of quality electronic equipment to increase the accuracy, convenience and utility of their instruments. The Helipot permits much finer adjustment of circuits and greater accuracy in resistance control. It permits simplifying controls and eliminating extra knobs. Its low-torque characteristics (only one inch-ounce starting torque*, running torque even less) make the Helipot ideal for power-driven operations, Servo mechanisms, etc.

And one of the most important Helipot advantages is its unusually accurate linearity. The Helipot tolerance for deviations from true linearity is normally held to within ± 0.5%, while precision units are available with tolerances held to 0.1%, .05%, and even less—an accuracy heretofore obtainable only in costly and delicate laboratory apparatus.

The Helipot is available in a wide range of types and resistances to meet the requirements of many applications, and its versatile design permits ready adaptation of a variety of special features, as may be called for in meeting new problems of resistance control. Let us study your potentiometer-rheostat problem and make recommendations on the application of Helipot advantages to *your* equipment. No obligation of course. Write today.

Send for the New Helipot Booklet!

THE Helipot CORPORATION, 1011 MISSION STREET, SOUTH PASADENA 6, CALIFORNIA

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(Continued from page 46A)

Sorg, H. E., 2015 Edgewood Rd., Redwood City, Calif.
Thompson, J. R., 115 W. McMicken Ave., Cincinnati, Ohio
Watts, J. M., 5304—41 Street, N. W., Washington, D. C.
Wesley, F. D., Prairie View, Tex.
Wever, L. R., Department of Electrical Engineering, University of South Cqrolina, Columbia, S. C.

The following admissions to Associate were approved on May 4, 1948, to be effective as of June 1, 1948:

Anderson, E. M., 1773 Lafond Ave., St. Paul 4, Minn.
Arnesen, R. F., 62 Clark St., Brooklyn 2, N. Y.
Ball, M. T., 74 Niagara St., Buffalo 2, N. Y.
Becker, J. G., R.F.D. 3, Kitchener, Ont., Canada
Bers, G. M., 1352 Sheridan St., N.W., Washington, D. C.
Bertola, J., Brown Boveri, Cia Sudamericana de Electricidad, San Martin 379, Buenos Aires, Argentina
Biascoechea, E., Box 114, 236 Carretera, Stop 33½, Hato Rey, Rio Piedras, P. R.
Blocker, C., 44-19 Ketcham St., Elmhurst, L. I., N. Y.
Boduch, T. S., 11 Tilson Rd., Toronto 12, Ont., Canada
Boffo, A. P., 3313 W. Walnut St., Chicago, Ill.
Boyle, B. H., 6019 Primrose Ave., Indianapolis, Ind.
Breitzer, D. I., 186 Tompkins Ave., Brooklyn 6, N. Y.
Brinn, J. M., 8035 Stahelin Ave., Detroit 28, Mich.
Bryan, C. R., Jr., 542 Cedarhurst Ave., Dayton 7, Ohio
Callahan, J. J., 144 School St., Somerville 43, Mass.
Capri, M. F., 5 King Ave., Albany 5, N. Y.
Crowley, D. J., Jr., 28 Bayard St., Allston 34, Mass.
Davis, J. S., Jr., 418 Forest View Rd., Linthicum, Md.
Dinning, J. R., 2371 Overland, Los Angeles 25, Calif.
Dusseau, A. E., Jr., 7413 Hawthorn Ave., Los Angeles 46, Calif.
Eadie, D., Apt. 44B, 44 Oak Grove Dr., Baltimore, Md.
Edwards, C. V., Demerara River, 330 Berbice Rd., McKenzie, British Guiana, S. A.
Erickson, R. S., 483 W. Lynnhurst Ave., St. Paul 4, Minn.
Fisher, A., 570 Lexington Ave., New York 22, N. Y.
Flower, R. A., 192 Mamaroneck Rd., White Plains N. Y.
Foulks, E. D., 239 W. Second, East Liverpool, Ohio
Gillespie, J. B., 208 W. Water St., Sandusky, Ohio
Graber, L. J., 158 Albertson Pl., Mineola, L. I., N. Y.
Hammer, A. C., Buchanan Heights, Valparaiso, Ind.
Haney, C. A., 5943 Race Ave., Chicago 44, Ill.
Hansen, A. S., Countryside, Mundelein, Ill.
Hartmann, E. E., 325 Leonard Ct., Danville, Ky.
Hauser, D. J., Box 265, Cuba City, Wis.
Helmer, P. M., R.F.D. 1, Box 71A, Osborn, Ohio
Hoffman, B. L., General Delivery, Lambertville, N. J.
Holmes, D. D., 1984 Harwood St., Lincoln 2, Neb.
Houlihan, R. P., Main St., East Brookfield, Mass.
Howe, J. H., General Delivery, Roanoke, Ind.
Javorsky, J. J., 4601 Springfield Rd., Dayton 3, Ohio
Johnston, C. J., 909 High St., Des Moines 9, Iowa
Jones W. G., 122 Adams Court Apts., Vidalia, Ga.
Joseph D., 1042 North Fifth St., Reading, Pa.
Kahn, B., 342 W. 18 St., New York 11, N. Y.
Kassel, P., 1571 Sheridan Ave., New York, N. Y.
Kimes, R. W., 6709A Newell St., Huntington Park, Calif.

(Continued on page 56A)

Department store demonstrations show how television makes shopping easier—saves time!

Shopping by Television—a coming convenience

You know television as an exciting source of news and entertainment. But what about its many other uses?

250,000 people—at a demonstration arranged by RCA Victor—learned the advantages of a "Shop-by-Television" program. Television receivers, conveniently located throughout a big store, showed customers what was going on in other departments . . . saved time . . . made shopping simpler.

88% of these customers said television was a major help . . . 62% said the program had drawn them to the store . . . more than half intended to visit departments where televised merchandise was sold. Sales of many televised items jumped 200% above normal!

Beyond its value *within* a store, "Shop-by-Television" is already reaching across the air waves to enter customers' homes. How convenient it will be to *see* merchandise on the screen of your RCA Victor television receiver, and then be able to do much of your shopping by telephone!

Such types of progressive research lead to new uses for radio-electronic products and services, and to the quality you associate with the names RCA, and RCA Victor.

• • •

When in Radio City, New York, be sure to see the radio, television and electronic wonders at RCA Exhibition Hall, 36 West 49th Street. Free admission. *Radio Corporation of America, RCA Building, Radio City, N. Y. 20.*

RCA ***RADIO CORPORATION of AMERICA***

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.

ENGINEER

Engineer—Transformer (power, audio and pulse). Thoroughly familiar with electronic circuits; production methods. Contact customers for technical purposes. Location about midway between New York and Chicago. Box 511.

ELECTRICAL ENGINEERS

Wanted electrical engineers with B.S. degree or equivalent experience for engineering application and operational work with electronic equipment—company conducting airborne geophysical surveys involving extensive United States or foreign travel—bonus for flying and and overseas duty. Box 512.

MICROWAVE ENGINEERS

Engineers or physicists for research and development in microwave field. B.S. degree essential, M.S. degree preferred. Positions open at both senior and junior levels. Salary commensurate with ability. Company has long term program and offers excellent working conditions including opportunity for advanced study. Location Brooklyn, N.Y. Give complete information in reply. Box 513.

ENGINEERS—PHYSICISTS

The Aeronautical Research Center of the University of Michigan at Willow Run, Michigan, has several openings for engineers and physicists with experience in the fields of servo-mechanisms, electronics and instrumentation. Interested applicants should furnish complete outline of experience with letter of application. University of Michigan, Personnel Office, 208 University Hall, Ann Arbor, Michigan.

BUYER

Steel buyer with knowledge of western New York market for nationally known radio manufacturing company. Excellent salary. Permanent. Fine future. Apply Rawle Deland, 1440 Broadway, New York 18, N.Y.

RESEARCH SCIENTISTS

Scientific research and development positions at the Naval Research Laboratory Washington, D.C. are open in the fields of physics, mathematics, engineering (including electronics, radio, electrical, mechanical, chemistry, metallurgy, etc.). A B.S. degree in the appropriate field from an accredited college or university is essential. Advanced academic standing

POSITIONS OPEN

and pertinent research experience is desirable. Both permanent and summer research and development positions are open. Qualified scientists are invited to communicate with Employment Officer, Code 151 (I), Naval Research Laboratory, Washington 20, D.C.

TECHNICAL RADIO ENGINEER

Radio engineer, capable of adjusting (or learning) complex directional antennas, for position with Washington consultant. State detailed qualifications, education and salary requirements. Box 514.

ELECTROLYTIC CAPACITOR ENGINEER

Exceptional opportunity for right man who can qualify for development engineering post with leading manufacturer. Please send complete particulars in first letter. Our men know of this advertisement. Reply Box 515.

TELEVISION ENGINEER

Chief engineer of television broadcast station located in midwest city. Please state fully experience and qualifications. Box 516.

RADIO RECEIVER ENGINEERS

Radio receiver engineers. Various types of qualifications. Please state experience and salary requirements in first letter. Box 517.

ENGINEERS

Allen B. DuMont Laboratories, Inc. have several openings in their Clifton plant for intermediate and senior engineers. Must have B.S. degree in physics or electrical engineering and experience in V.H.F., television deflection or general circuit development. Apply personnel Dept., 1000 Main Ave., Clifton, New Jersey. 9:00 A.M. to 3:00 P.M.

ELECTRONIC DESIGN ENGINEER PRODUCTION ENGINEER

(1) ELECTRONIC DESIGN ENGINEER—Boston firm developing electronic instruments for radioactivity detection and measurement. Offers excellent opportunity for high calibre design engineer. Write full details.

(2) PRODUCTION ENGINEER—Boston firm manufacturing electronic radioactivity instruments has opening for qualified man experienced in engineering production models from prototype designs. Position also entails responsibility for component and production quality control. Write full details. Box 518.

COMMUNICATIONS ENGINEERS

Communications engineers to staff a new division in California civil service will be selected by examinations on July 8, 1948. Engineers at senior level are paid monthly salary ranging from $458-$556. Associate level salary range $395-$481. College graduates with a major in engi-

(Continued on page 52A)

COMPUTER ENGINEER

●

Nationally known organization seeks experienced engineer to assist in construction and operation of large scale electronic digital computers. This is a permanent position with operating company. To conserve your time and ours, letter should include complete summary of personal and professional data, including education, management and business background, religion, dependents, salary requirements and references. This is an outstanding opportunity for qualified man. Address Box No. 720.

THE INSTITUTE OF RADIO ENGINEERS
1 East 79th St.
New York 21, N.Y.

SENIOR AUDIO ENGINEER

Long established company located in metropolitan area of New York City has opening as head of one of the engineering groups of the company. This company manufactures audio amplifiers, telephone equipment, transducers etc.

Man desired will have opportunity made possible by transfer of former section head to work in another field.

Must be graduate electrical engineer. Experienced in miniature circuit components, telephone relays, receivers, circuits etc., highly desirable. Knowledge of theory and production practice essential, as well as ability to control cost and schedules.

Box No. 525
The Institute of Radio Engineers
1 East 79th St.
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Engineers—Electronic

Senior and Junior, outstanding opportunity, small growing company. Forward complete resumés giving education, experience and salary requirements to

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RADIO and RADAR
Development and Design Engineers
Needed by
HAZELTINE ELECTRONICS CORPORATION

Please furnish complete resumé of experience with salary expected to: *Director of Engineering Personnel, Hazeltine Electronics Corporation, Little Neck, Long Island, New York.* (All inquiries treated confidentially)

POSITIONS OPEN

(Continued from page 51A)

neering or physics and 3 years engineering experience in the fields of electrical communications are required for associate level. Seniors must have 5 years engineering experience, including 2 in design or operation of radio communication systems. Exams will be held throughout the U.S. Those who pass written test must appear for oral interview in Calif. Details of requirements and application blanks may be secured from the State Personnel Board. 1015 L St. Sacramento 14, Calif.

TELEVISION INSTRUCTOR

Television instructor wanted by a television training institution of long standing in Hollywood; must be well versed in the principles and practice underlying television transmitting and receiving. Minimum $3,200. State particulars, including educational and experience background. Box 521.

MATHEMATICIANS, ENGINEERS, PHYSICISTS

Men to train in oil exploration for operation of seismograph instruments, computing seismic data, and seismic surveying. Beginning salary—open depending upon background; excellent opportunity for advancement determined on ingenuity and ability. Nature of work requires several changes of address each year; work indoors and out; general locations in oil producing states. To apply, write giving scholastic and employment background, age, nationality, marital status and include recent snapshot to National Geophysical Co., Inc., 8800 Lemmon Ave., Dallas 9, Texas.

ELECTRONIC ENGINEERS

Salaries $3021 to $4149 per annum. In charge of major field communication installation projects including electronic, radio, and teletype equipment system. Contact Civil Aeronautics Administration, 385 Madison Ave., New York 7, N.Y.

ELECTRONIC ENGINEER

Salary $4902 per annum. Responsible for the type certification of radio and electronic equipment as well as for its installation in aircraft and for engineering approval of aircraft electrical systems. Contact Civil Aeronautics Administration, 385 Madison Ave., New York 7, N.Y.

PROFESSOR OF COMMUNICATION ENGINEERING

Professor of communications engineering needed for fall 1948 by southeastern university. Will be in charge of graduate work and research activities. $6000.00 for nine months with extra income for summer teaching. Must have Ph.D. or D.Sc. degree. Write Box 522.

PROJECT ENGINEERING

Electronic engineer with practical background in television is required by small television manufacturer to act as project engineer on television distribution systems. Metropolitan New Jersey. Box 523.

★ ★ ★ ★

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.

ENGINEER

Engineer, 25 years old desires personnel or contact position where three years as a Signal Corps officer followed by two years of electronic laboratory and factory experience will pay dividends. Married and will locate anywhere. Box 142W.

DESIGN AND DEVELOPMENT ENGINEER

Design and development engineer—extensive experience FM and VHF, broadcoast equipment and audio, some microwave. Both theoretical and practical background. Registered Professional Engineer. Employed, but good reason for desiring change. Box 143W.

ENGINEER

Ph.D. candidate (physics) completing second year scholastic requirements by May. Available June 1st for employment in metropolitan area. Vacuum tube, electronics etc. B.S., M.S. physics. Strong minor in chemistry. Captain, radar A.U.S. Graduate Harvard, M.I.T. Electronic Training Center. Box 153W.

PHYSICIST

B.S. 1942. Age 26. Single. Four years research laboratory experience, with some electronics training received in Service. Desires development work preferably in southwestern U.S. Box 154W.

EXECUTIVE ENGINEER

Desires administrative position in Los Angeles area. Extensive administrative and electronic engineering experience. M.S. degree Harvard. Box 155W.

JUNIOR ENGINEER

Graduating University of Michigan in June 1948 with B.S.E.E. (communications) and B.S.E. (mathematics). Tau Beta Pi, Eta Kappa Nu. One year experience Navy electronics. Interested in television broadcasting, production or development. Details on request. Box 156W.

(Continued on page 54A)

Positions Wanted

(Continued from page 53A)

ELECTRONIC ENGINEER

B.S.E.E. Jan. 1948, Cooper Union. Age 23. Two years experience as electronics technician, U.S. Navy. Would like position preferably in the vicinity of New York. Box 157W.

JUNIOR ENGINEER

B.S.E.E. from University of Illinois in 1948. Navy experience in radar and sonar. Seeks position as junior engineer in electronics. Prefers vicinity around New York City. Box 158W.

ADMINISTRATIVE ENGINEER

Business administration plus engineering training. M.B.A. Harvard Business School, June 1948. B.E.E. Rensselaer, 1942. Tau Beta Pi, Sigma Xi. Age 26. Navy radar and patent experience. Desires job in small to medium size concern. Box 159W.

PATENT ENGINEER

B.E.E. Illinois Institute of Technology. Now enrolled graduate law school patent course. 10 years diversified experience—research, production, army radio instructor, radar, etc. Desires patent position. New York area or Chicago preferred. Box 170W.

RADIO ENGINEER

Interested in going abroad. Will graduate with B.S. in E.E. in June. Already have degree in radio engineering. Age 23. Single. Willing to locate in almost any country. Box 171W.

ENGINEER

B.S.E.E. June 1948, Columbia University. Age 28. Married, two children. Officer, Army Signal Corps, 2½ years, administrative and communication experience. Desires sales engineering or administrative position in New York area. Occasional travel possible. Box 172W.

JUNIOR ENGINEER

B.E.E. graduating June 1948. Tau Beta Pi, Eta Kappa Nu. Prefer metropolitan area, anywhere near a graduate school. Box 173W.

ENGINEER

B.S.E.E. from University of Florida June 1948. 3 years experience in communications work in Army Air Forces. Would like position in audio engineering or allied fields. Any location within the United States. Box 174W.

JUNIOR ENGINEER

Wants summer employment New York or New Jersey. Junior E.E. Clarkson College of Technology. Graduate of 7 radio and radar courses—5 schools, including N.Y.U. (Pre-radar) as civilian and during 3½ years in army. 1 year A.A.F. instructor airborne radar. 1½ years experience with standard broadcast 1st class F.C.C. license. Experience also in induction heating and c.r.t. construction. Single. Age 24. Box 175W.

Positions Wanted

ELECTRICAL ENGINEER

B.S.E.E. Illinois Institute of Technology 1948. Age 27. Married. 2½ years Signal Corps. Installation and maintenance of radio equipment. 2 years electronic instrument experience. 1st class radiotelephone license. Desires position with opportunity for advancement. Box 176W.

JUNIOR ENGINEER

Graduate, west coast radio and television school. Single. Age 28. 1st class phone. 2½ years AAF as VHF specialist. Now employed Navy guided missile base. Desires position with television station, preferably maintenance. Will work any where in U. S. Box 177W

JUNIOR ENGINEER

College Junior, Syracuse University Age 25; Army experience 3 years VHF link-carrier; amateur license; interested in summer 1948 position. Location irrelevant. Box 169W.

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 24A)

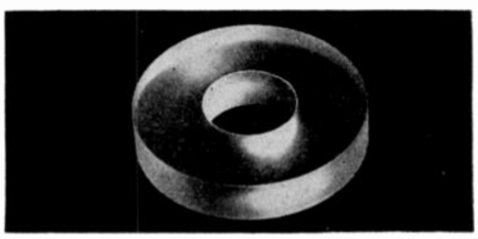
New "Range-Master" Features Protective Built-in Fuse

Encompassing a wide range, and incorporating a standard Littelfuse which protects the meter movement, rectifier, and shunts against overload on all ranges, a new Model 10-F "Range-Master" has been developed by **Bradshaw Instruments Co.,** 348 Livingston St., Brooklyn 17, N. Y.

The 10-F covers the following ranges: (1) capacitance—0.001–0.1, 0.01–1, 0.1–10 μfd.; (2) a.c.—0–.15, 0–1.5, 0–15 amperes; (3) a.c. voltage—1, 10, 100, 500, 1000 volts; (4) d.c. voltage—10, 100, 500, 1000 volts; (5) d.c.—1, 10, 100, 1000 milliamperes; (6) resistance—0 to 10,000, 100,000, 1 megohm; (7) special high-range ohmmeter to 2 megohms and 20 amperes without external battery; and (8) sensitive a.c. microammeter to 1100 microamperes.

Direct reading on all ranges insures rapid circuit analysis. Using wire-wound calibrating controls for accuracy, and an exclusive sealed-in manganin wire-wound shunt, the 10-F employs 1% carbofilm multipliers. Portable model measures 8¾"×7½"×4"; bench model, 5¼"×6¾"×2¼".

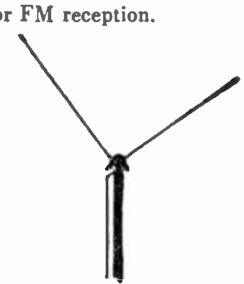
(Continued on page 57A)



MEMBERSHIP

(Continued from page 48A)

King, C. B., 215 W. Center St., Lebanon, Ill.
Klein, J. J., 611 W. 148 St., New York 31, N. Y.
Kobi, J., 101 E. 87 St., New York 28, N. Y.
Lauderdale, D. M., ET annex NATC, Patuxent River, Md.
Lawrence, G., 1122 Brown Ave., Columbus, Ga.
Lee, R. H., 511 Fifth Ave., New York 17, N. Y.
Lee, R. E., 143-26 Ash Ave., Flushing, L. I., N. Y.
LeFever, C. F., 615 S. Darling St., Angola, Ind.
Lepage, J. L., Deep River, Ont., Canada
Levin, J., Alvarez Thomas 1326—4 piso Dept. 5, Cuerpo B., Buenos Aires, Argentina
Lietzen, A. A., 6815 Eighth Ave., Los Angeles 43, Calif.
Lyle, I. W., Jr., 1806 Radnor Ave., Louisville 5, Ky.
Malinowski, E., 25 Warnes, Buenos Aires, Argentina
Mercer, J. P., 4917 First St., N.W., Apt. 3, Washington 11, D. C.
Mette, R. J., 2231 N. Mulligan Ave., Chicago 39, Ill.
Moore, F. H., 4315 N. Fourth St., Apt. 101, Arlington, Va.
Monroe, J., 339 New York Ave., Brooklyn 13, N. Y.
Morrissey, R. D., 15 Bigelow St., Cambridge 39, Mass.
Moy, M., 49 Massachusetts Ave., Boston, Mass.
Nelson, M. D., 1267 Grant Ave., New York 56, N. Y.
Ordesch, W. E., J. N. Ceazan Company, 1700 S. Figueroa St., Los Angeles, Calif.
Oxner, E. S., 319 S. Darling St., Angola, Ind.
Paneyko, M., Fairfield 10, Conn.
Parlett, W. G., Box 105, Angola, Ind.
Pelowski, S. F., 1212 N. LaSalle, Chicago 10, Ill.
Petrovich, M. L., 1136 W. Lill Ave., Chicago 14, Ill.
Plum, M. J., 35-27—72 St., Jackson Heights, L. I., N. Y.
Probert, L. J., 304 Erie St., Valparaiso, Ind.
Quick, J. D., 616 E. Broad St., Angola, Ind.
Rao, P. R., c/o Sri P. Vyasa Rao, Retd. District Munsif., Kadri Rd., Mangalore, South India
Reid, T. D., 2809—15 St., N.W., Washington 9, D. C.
Richards, A., 7201 72 Ct., Brooklyn, N. Y.
Rink, J. F., Box 1897, Anchorage, Alaska
Roach, W. E., Box 72, Lawrenceburg, Ky.
Robertson, R. E., 4430 Main St., Snyder 21, N. Y.
Rowe, H. S., 20, Groathill Ave. Edinburgh 4, Great Britain
Roy, H. L., Radio Station KSYL, Alexandria, La.
Sack, A., 74 Glenville Ave., Allston 34, Mass.
Schmid, E. R., 75 Irving Ave., Brooklyn 27, N. Y.
Seshadri, G., Beam Wireless Station, Poona 6, India
Sims, D. S., Westinghouse Research Laboratories, East Pittsburgh, Pa.
Smith, F. B., Radio Station KSYL, Alexandria, La.
Smith, W. F., Jr., 517 Cook St., Denver 6, Colo.
Snooks, W. E., 2217 Fourth St., S.W., Akron 14, Ohio
Spalding, R. L., 4703 Market St., Youngstown, Ohio
Spoor, T. A., Apartado Postal 7255, Mexico, D. F.
Sterk, A. A., 320 W. 76 St., New York 23, N. Y.
Stewart, H. K., 708 Greenwood Ave., Takoma Park 12, D. C.
Swaringen, C. T., Jr., 1059 Miller St., Winston-Salem 7, N. C.
Teece, K. A., 13, Kenilworth Rd., London W.5, England
Tufro, A., 12 W. 56 St., New York 19, N. Y.
Turner, T. L., 188 W. 135 St., Apt. 4E, New York, N. Y.
Wallmark, J. T., 104 Jefferson Rd., Princeton, N. J.
Wayne, S. J., c/o Paris, 9 Wyckoff St, Matawan, N. J.



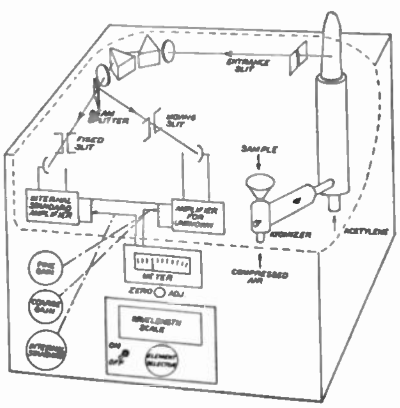
News—New Products

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

(Continued from page 55A)

Internal Standard Flame Photometer

The Model 52-A Flame Photometer has been developed by the **Perkin-Elmer Corp.,** Glenbrook, Conn. for the analysis of the alkali and alkaline-earth elements. Provision for internal standard measurements with their higher accuracy is featured with the new instrument. The instrument also incorporates an a.c. amplification system with chopped light and synchronous amplification at the output. This provides the amplifier system with high sensitivity and maximum flexibility. Sodium, potassium, and lithium may be detected in concentrations down to 1/10 part per million. Good analyses can be made anywhere in the range from 10 to 1000 ppm. Calcium may be detected down to 1 part per million. For the other alkaline earth elements the sensitivity is somewhat less. 5 cc of sample is required for each determination, and accuracies of plus or minus 1% to 2% of the amount present are obtainable in the range of favorable concentrations.



The cutaway drawing shows schematically the general arrangement and operating principles. The sample is poured into the inlet funnel of an atomizer. A fine fog separated from the atomized spray in the glass atomizer chamber is blown into the base of the burner. When mixed with gas and burned, it colors the flame with the characteristic spectra of the salts it contains. The entrance slit of a two-prism monochromator looks directly at the center of the flame just above the top of the burner. Light from the flame is dispersed into a spectrum and divided by a beam-splitting mirror so that part falls on a fixed exit slit and part on a movable one.

For internal standard measurements, 2 phototubes measure simultaneously the amounts of light at two different wavelengths in the spectrum. One of them is set for the wavelength of the lithium emission lines used as the internal standard; the other is adjustable for the selection of different elements. The intensities of the lights falling on the two are balanced

(Continued on page 58A)

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 57A)

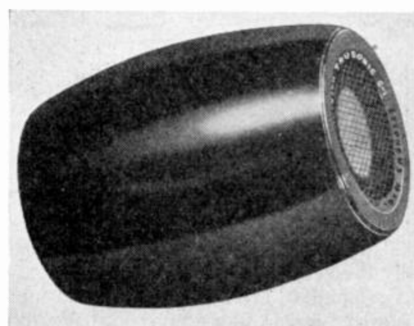
against each other, to read their ratio directly. Of course, direct intensity measurements may also be made without the use of the internal standard.

Features that are not shown in the figure are the vibrating shutter and synchronous rectifier included to permit the use of ac amplification, and the connection from the element selector and wavelength scale to the moving slit. Additional amplification makes the final output large enough to read on a meter.

The instrument can burn either propane or acetylene merely by changing the grid on the top of the burner. The flame recommended for the determination of sodium, lithium and potassium is propane and air. Acetylene is used to give a hot flame for the determination of the other elements. The amplifier operates on 110-volt, 50- or 60-cycle power. Compressed air at 20 to 150 pounds per square inch is needed for the atomizer. Pressure regulators are included for the air and gas supplies.

Phase-Modulated Microphone

Announcement of the "Tru-Sonic Phase-Modulated Model C-1" microphone has been made by **Stevens Manufacturing Corp.**, 10416 National Blvd., Los Angeles 34, Calif.



The principle of carrier-frequency phase modulation is employed. Measurements of the ovoid-shaped pickup assembly are $1'' \times 1\frac{1}{4}''$.

Other features claimed by the manufacturer are: (1) true and absolute linearity of response—low response is linear to one-half cycle in 24 hours, (2) no distortion can be read or detected, (3) no arc-over or breakdown, (4) pressure-operated at all frequencies, (5) polar pattern at all frequencies—almost completely one-half sphere, down 5 db at 90° off the axis, (6) signal-to-noise ratio at least 11 db higher than the best prior microphones, (7) pick-up unit contains only the acoustic valve and carrier-matching coil. It is of such rugged construction that the valve assembly may be thrown on the floor without damage.

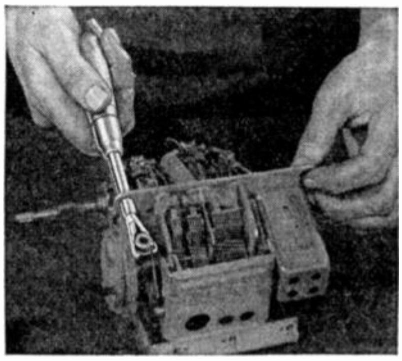
(Continued on page 59A)

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 58A*)

Grommet Inserter



This tool has recently been developed by **D. B. Rich Manufacturing Co.,** 6217 N. Melvina Ave., Chicago 30, Illinois to efficiently simplify grommet inserting.

Each insertion takes only a few seconds. The nose of the tool is slipped through the hole which is to receive the grommet. The operator places a grommet into the claw nose, withdraws the tool, and the grommet is automatically inserted in position. Snug, perfect fitting is insured because undersized grommets need not be used to make inserting easier. Damage to grommets ordinarily caused by forcing and jamming methods is eliminated when using this new device.

The inserting claw has only one moving part, decreasing the possibility of malfunction. It is available in four standard sizes for instering $\frac{1}{4}''$, $\frac{5}{16}''$, $\frac{3}{8}''$ and $\frac{7}{16}''$ grommets. Custom sizes made to order.

Constant Voltage for Mercury-Vapor Lamps

Announcement of the Sola Type CVM-1 constant voltage ballast transformer by **Sola Electric Company,** 2525 Clybourn Ave., Chicago 14, Illinois, marks the formal extension of the Sola constant-voltage principle to the field of high-pressure, high-intensity mercury-vapor-lamp controls. The Type CVM-1 ballast transformer is a unit specifically designed to protect and stabilize the operation of the G. E. Type UA-4 mercury-vapor lamp and offers advantages over high-reactance ballast transformers.

Operation of the lamp is completely stable and free from the effects of improper or widely varying line voltage. Lamp life is increased by preventing over-voltage operation. Lamp outages resulting from momentary voltage drops are eliminated. There can be no damage to the lamp from improper selection of primary taps. Constant spectral distribution of light output is maintained. Inherently high input power factor permits operation of lamp on 115-volt lighting circuits. The Type CVM-1 is entirely automatic, has no moving parts, and requires no maintenance or adjustments.

(*Continued on page 60A*)

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 59A)

Constant-voltage ballast transformers are also available, or under development, for a number of other mercury-vapor-lamp applications.

Recent Catalogs

• • •On "the magic of making television picture tubes," an illustrated folder in color by the **Dept. of Information, R.C.A.,** 30 Rockefeller Plaza, New York 20, N. Y.

• • •On how other plant engineers and electrical maintenance men are using snap-action switches, **Micro Tips by Micro-Switch,** Freeport, Ill.

• • •On how oscillograph operation was unaffected in high acceleration and shake-table tests, in **"CEC Recordings,"** by **Consolidated Engineering Corp.,** 620 N. Lake Ave., Pasadena 4, Calif.

• • •On various types of crystal units including a plated-type wire-mounted unit, hermetically sealed and filled with dry nitrogen. Fundamental frequencies from 1 to 2 Mc can be supplied with tolerances from 0.02% down to 0.003% over a temperature range—55 to 90 C°, by **Standard Piezo Co.,** P. O. Box 164, Carlisle, Pa.

• • •On high-strength corrosion-resisting alloys with a chart and an offer of free samples to test under your own conditions on page 1, by **Haynes Stellite Co.,** Kokomo, Ind.

• • •On a chimney mount antenna base, extremely light weight and rapidly installed (antennas may be mounted in series), by **South River Metal Products** Co., South River, N. J.

• • •On capacitors, contacts, rectifiers, resistors, switches, vibrators, welding tips and holders, and various special metals and alloys, by **P. R. Mallory & Co., Inc.,** 3029 E. Washington St., Indianapolis 6, Ind.

• • •On antennas and a chart by Charles Valach on rf connector characteristics, the **Amphenol Engineering News, by American Phenolic Corp.,** 1830 So. 54th Ave., Chicago 50, Ill.

• • •On their 56th Annual report for the year ended December 31, 1947 by **Philco Corporation,** Lioga & C Sts., Philadelphia 34, Pa.

• • •On a newly designed Model HPL High Speed Recorder. Requests for the bulletin "Sound Advances" will be promptly complied with by **Sound Apparatus Co.,** 233 Broadway, New York 7, N. Y.

• • •On Operation Recorders, with a guide to assist in determining their selection and use, "The Graphic," Bulletin 247 by **Esterline-Angu~ Co., Inc.,** Indianapolis, Ind.

News—New Products

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

(Continued from page 60A)

• • •On multipurpose step-down transformers with five wiring schematics to illustrate their uses and advantages, by **Electran Mfg. Co.,** 4587 N. Elston Ave., Chicago 30, Ill., in their bulletin 47A.

• • •On new and more complete data on all commercially available types of "Silastic" the Dow Corning Silicone Rubber, in "Silastic Facts No. 5," a 16 page booklet by **Dow Corning Corp.,** Midland, Mich.

• • •On a list of relays, timing devices, and location of sales engineering offices in the 1948 catalog by **Potter & Brumfield Sales Co.,** 549 W. Washington Blvd., Chicago 6, Ill.

• • •On complete and kit television receivers with listings of twenty-five prominent manufacturers in the field, "The Rider Television Manual," Volume 1, by **John F. Rider, Publisher, Inc.,** 404 Fourth Ave., New York 16, N. Y.

• • •On electronic timers employing RCA thyratrons 2D21 or 2050 with several schematic diagrams of circuits by **RCA Tube Dept.,** Harrison N. J. Request March issue.

• • •On "Trancors by Lenkurt," a new 24-page folder describing the complete line of moulded magnetic cores, core assemblies, and filters manufactured by **Lenkurt Electric Co.,** 1129 County Road, San Carlos, Calif.

PRODUCT INFORMATION

in 72 Engineering Classifications

for 2000 Supply Firms

will appear in your 1948 I.R.E. Yearbook coming out in July.

An alphabetical listing is given for all manufacturers who have provided us up-to-date product data. Listing shows the firm's complete radio-electronic line.

Complete product index is given on 120 leading firms who are advertising in the Yearbook.

"Look in the I.R.E. Yearbook."

News—New Products

Atomic Energy Commission Orders Radiochemical Compounds

The Atomic Energy Commission has enlisted the services of **Tracerlab, Inc.,** 55 Oliver Street, Boston, Mass., to manufacture and stock a number of compounds tagged with carbon-14, for which there is a widespread need in research problems.

A substantial contribution to more extensive use of radioisotopes in research is expected to be achived in a new cooperative venture between the Atomic Energy Commission and private industry.

This new program should have several beneficial results. First, a variety of tagged compounds will be made available to many research groups who otherwise would not be in a position to synthesize them. Second, it is hoped that the synthesis of these compounds on a relatively large scale will result in a substantially lower cost than if they were made for a single customer. Third, it is believed that considerable time will be saved by having such compounds available for immediate shipment upon receipt of an order approved by the Atomic Energy Commission.

To obtain, apply for Form 313, "Application for Radioisotope Procurement," to the Isotopes Division, U. S. Atomic Energy Commission, P. O. Box E, Oak Ridge, Tenn.

Barium carbide tagged with carbon-14 is available for immediate delivery at $150.00 per millicurie with a specific activity of two millicuries per millimole. The cost of the carbon-14 is included in this price.

Carbon-14-labeled sodium cyanide is available from stock at a price of $250.00 per millicurie.

Interesting Abstracts

Federal Telephone and Radio Corp., 100 Kingsland Road, Clifton, N. J., have released an explanatory booklet describing "Intelex," and automatic reservation exchange for airline travel, which is comparable to an automatic telephone exchange.

This electrically operated device almost entirely eliminates manual operation, and decreases the time expended in making a reservation from hours to a matter of seconds.

Intelex automatically checks availability of the space requested. If available, the machine advances its storage recorder one place for each seat requested, and answers over the teleprinter by repeating the message and adding a serial number. This serial number tells the clerk that the space requested is confirmed.

The complete operation normally requires less than 20 seconds and eliminates entirely the possibility of making duplicate sales.

News—New Products

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

Standardized Interchangeable Components For New Welding Guns

Standardized spot-welding guns designed with and constructed from standardized interchangeable component parts are now being produced by **Progressive Welder Co.,** 3050 E. Outer Drive, Detroit 12, Michigan.

Seven basic gun types, in heavy-duty and standard-duty versions, will take care of 95% of all gun welding requirements. Moreover a gun can be quickly converted to a different job by simply changing one or two standardized parts.

With this standardization of components it is possible to obtain as many as 57,600 variations with a single basic gun chassis, varying only jaw extensions and standard electrodes.

Jaw extensions are available in increments of length from 1 to 6 inches and with four (0°, 10°, 20° and 30°) variations for the angle at which electrodes are mounted. Chassis jaws are equipped with clamp-type locks, while jaw extensions have O-ring type seals effectively preventing leakage.

Special variations include manually retractable or rotary jaws, to clear extremely wide flanges; special jaw extensions and point adaptors to suit unusual conditions; linkages to provide extra long stroke; stroke decreasers (to reduce the normal return stroke of a gun for exceptionally fast operation); self-locking hydraulic cable terminal clamps which permit the gun to be swiveled free of the cable until welding pressure is applied.

Recent Catalogs

• • •On a wide variety of special military motors, with circulars briefly describing their specialized tasks, also small 5- and; 10-watt output two-phase servo motors; by **Eastern Air Devices,** 130 Flatbush Ave., Brooklyn 17, N. Y.

• • •On electric branding irons, with inclosed lists of instructions for ordering, materials that may be branded, use of the iron, and suggestions for designing a brand which will be effective and economical by **Hexacon Electric Co.,** 181 W. Clay Ave., Roselle Park, N. J. Request No. 300.

• • •On Kodak Linagraph films and papers for use in instrument recording, issued by **Industrial Photograph Division, Eastman Kodak Co.,** Rochester 4, N. Y.

• • •On a price list of magnetic wire, and a listing of sales offices and warehouses in important cities, by **Essex Wire Corp.,** Fort Wayne 6, Ind.

• • •On small high-voltage capacitors, designed exclusively for television with three types of terminals for flexibility and convenience and made with "Ceramic-X," by **Centralab Division of Globe-Union, Inc.,** Milwaukee 1, Wis.

Attention

Associate Members!

Many Associate Members can qualify for higher membership grades and should certainly do so. Members are urged to keep membership grades up in pace with their present development.

An Associate over 24 years of age who is occupied as a radio engineer or scientist, and is in this active practice three years may qualify for Member Grade.

An Associate who has taught college radio or allied subjects for three years may qualify.

Some may possibly qualify for Senior Grade. But transfers can be made only upon your application. For fuller details request transfer application-form in writing or by using the coupon below.

IRE

Coupon

Institute of Radio Engineers
1 East 79th St.,
New York 21, N.Y. 6-48

Please send me the Transfer Application Membership-Form.

Name ....

Address ....

Place ....

State ....

Present Grade ....

INDEX AND DISPLAY ADVERTISERS

DISPLAY ADVERTISERS

> Those firms coded "YB" in the above index are providing additional product data in advertisements in the I.R.E. Yearbook coming out this summer. I.R.E. Members will find these ads provide working facts.

Electronic Market #1

16,930 Radio Engineers





This is the story of a technical market which consumes millions of dollars of components, instruments, materials and transmitting equipment annually to make up the two billion dollar radio-electronic industry.

Manufacturers tell us that nearly half of all their sales are "audience sales" made through advertising, or mass selling. The reason is understandable — it takes a sales engineer to do this kind of selling; and they are hard to get. The engineer is the buyer; and he is hard to reach.

But it is not hard to sell the radio industry if you tell your story to the radio engineer using a medium which talks his language; his monthly technical journal, "Proceedings of the I.R.E." for promotional copy, and his annual "I.R.E. Yearbook" for reference data ads. These publications can serve you as a sales engineer staff big enough to contact 16,930 engineers, all qualified I.R.E. members. Our new A.B.C. statement will give you audited facts on this Electronic Market #1. Ask us for a copy, today.

The illustrations show some of the scenes from the 1948 Radio Engineering Show at Grand Central Palace, March 22-25 which attracted 14,800 men to technical exhibits. Thus the I.R.E. brought a major segment of the "Proceedings" audience right to its advertiser-exhibitors.

THE INSTITUTE OF RADIO ENGINEERS

Proceedings of the I.R.E.

I.R.E. Yearbook **Radio Engineering Show**

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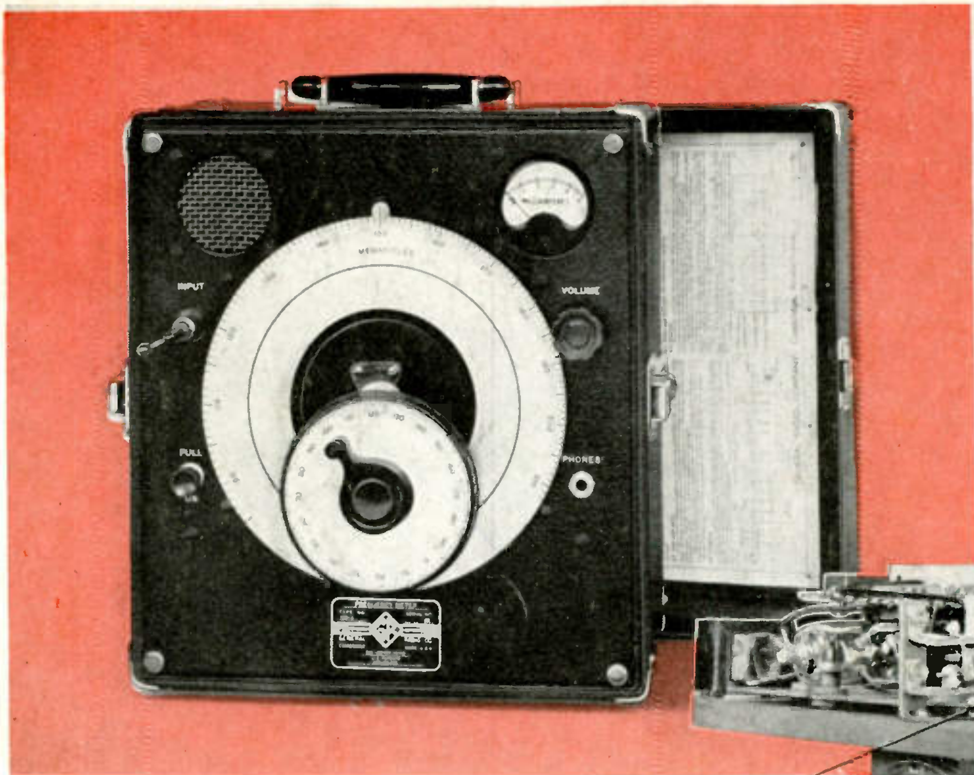

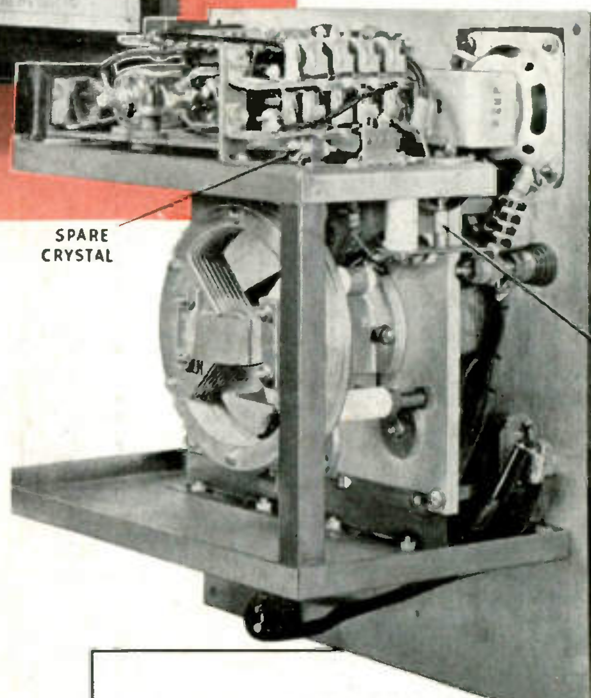

FREQUENCY MEASUREMENTS TO 3,000 Mc

FULL advantage of the simplicity of the heterodyne method of frequency measurement is taken in this frequency meter. With a fundamental range of 100 to 200 megacycles, accurate frequency measurements may be made between 10 and 3,000 megacycles.

The tuning circuit is our butterfly type with no sliding contacts, obviating many of the difficulties encountered in the usual tuning elements used in u-h-f equipment.

A standard plug-in silicon crystal is used as the detector, followed by a three-stage audio amplifier. The band width of the amplifier is 50 kc to permit visual beat indication even if the signal under measurement is unstable.

For very strong signals beat indication may be obtained either aurally from the built-in dynamic loud speaker or visually from the panel meter. For weak signals a telephone jack is provided for headset detection.

Normally no direct connection to the signal under measurement is required, the retractable 'antenna' providing the necessary coupling. On weak signals, terminals are provided for additional pick-up if necessary.

This instrument is finding wide application both in the laboratory and in the field where a portable, self-contained, stable and accurate heterodyne frequency meter is needed for measurements over a very wide range of high and ultra-high frequencies.

TYPE 720-A HETERODYNE FREQUENCY METER $340

SPECIFICATIONS

FREQUENCY RANGE — fundamental range of instrument is 100 to 200 Mc; by harmonic methods measurement range is 10 Mc to 3,000 Mc.

CIRCUIT — our butterfly tuning unit used in the oscillator; crystal detector (with spare); 3-stage audio-frequency amplifier.

BEAT INDICATORS — built-in dynamic loud speaker and panel meter for aural and visual beat indication; telephone jack for headset indication from weak signals.

ACCURACY — over-all accuracy is ± 0.1%

CALIBRATION — main dial calibrated in frequency, each division being 1 Mc; one-half turn of vernier dial corresponds to approximately 1% change in frequency over entire tuning range.

PORTABILITY — instrument weighs only 27½ pounds complete with batteries. Separate a-c power supply may be ordered for a-c operation.

GENERAL RADIO COMPANY Cambridge 39, Massachusetts

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