COMMUNICATIONS

$1.00

INCLUDING "RADIO ENGINEERING" AND "TELEVISION ENGINEERING"

MAY 1946

★ FCC A-M APPROVED BROADCAST TRANSMITTERS ★ ANALYSES OF TRANSMISSION LINES

★ F-M SATELLITE SYSTEM FOR RAILROAD COMMUNICATIONS

RAYTHEON'S NEW STUDIO CONSOLE

For AM or FM

Compare THESE OUTSTANDING FEATURES WITH ANY OTHER CONSOLE

Easily Controls Two Studios, Announcer's Booth and Nine Remote and Two Network Lines

COMPLETE high-fidelity speech-input facilities for the modern station; this single compact unit contains all the control, amplifying and monitoring equipment. Any combination of studios, remote lines or turntables may be broadcast and auditioned simultaneously through the two high quality main amplifier channels. On-coming programs may be cued and the volume pre-set while on the air.

Its modern functional beauty in two-tone metallic tan will blend with other equipment and yet add a definite air of quality and distinction to your studio. Sloping front panel combines maximum visibility of controls with ease of operation. Sloping top panel gives operator an unobstructed view into the studio.

Engineered for dependability and built of finest quality components throughout. Telephone-type lever action, 3 position key switches assure trouble-free operation and *eliminate nineteen controls*. This simplified switching reduces operational errors. All controls are standard, simple and positive—easy to operate.

Inquire! The low price of this Raytheon Console will amaze you. The first orders are now being delivered. Write to:

1. Seven built-in pre-amplifiers—*more than any other console*—making possible 5 microphones and 2 turntables, or 7 microphones, on the air simultaneously.

2. Nine mixer positions—*more than any other console*—leading to 5 microphones, two turntables, one remote line and one network line.

3. Nine remote and two network lines—*more than any other console*—may be wired in permanently.

4. Telephone-Type lever-action key switches used throughout—most dependable, trouble-free switches available. No push buttons.

5. Frequency Response 2 DB from 30 to 15,000 cycles. Ideal speech input system for either AM or FM.

6. Distortion less than 1%, from 50 to 10,000 cycles.

7. Noise Level minus 65 DB's or better. Airplane-type four-way rubber shock mounting eliminates outside noise and operational "clicks."

8. All FCC Requirements for FM transmission are met.

9. Dual Power Supply provides standby circuit instantly available for emergency use.

10. Power Supply designed for mounting on desk, wall or relay rack.

11. Instant Access to all wiring and components. Top hinged panel opens at a touch. Entire cabinet tilts back on sturdy full-length rear hinge.

RAYTHEON MANUFACTURING COMPANY

Broadcast Equipment Division, 7517 N. Clark Street, Chicago 26, Ill.

RAYTHEON

Excellence in Electronics

Devoted to Research and Manufacture for the Broadcasting Industry

A MULTI-PURPOSE AMPLIFIER

of Broadcast Quality

Langevin 114-A Amplifier in 204-A Cabinet

THE Langevin 114-A Amplifier is primarily a monitor amplifier. It is used in offices, audition and control rooms of radio stations and recording studios, and also fits the needs of wired music installations and other industrial uses wherever an amplifier for a single or dual speaker installation is required.

This amplifier operates on 110-120 volts AC or DC. It can be rack mounted or used in its own metal cabinet, Type 204-A; it has a frequency response of 30 to 15,000 cycles and delivers 3 watts of audio power at less than 2% RSS total harmonic distortion at 400 cycle single frequency. At 4 watts output the distortion is less than 5%.

ELECTRICAL CHARACTERISTICS

GAIN—Approximately 61 db high gain and 43 db when bridging a 600 ohm source. **OPERATES FROM**—0-1000 ohms using nominal 600 ohm input, 0-25,000 ohms using nominal 25,000 ohm input, with maximum gain depending upon impedance of bridged source. **OPERATES INTO**—Nominal load impedance of 4 ohms. Working range 2 to 8 ohms. **OUTPUT POWER**—Approximately 4 watts with less than 5%, and 3 watts with less than 2%, RSS total harmonic distortion at 400 cycles single frequency into nominal 4 ohm load. **OUTPUT NOISE** 42 db below +35 VU (7 db below .001 watt) or better. **FREQUENCY CHARACTERISTIC** — Production run ±1.5 db over the range of 30-15,000 cycles. **POWER REQUIREMENT**—110-120 volts, 25-1000 cycles AC, or 110-120 volts DC. Amplifier draws 70 watts at 120 volts. **SIZE**—Maximum length 10¼", depth 6½", height 6¾".

The Langevin Company

INCORPORATED

SOUND REINFORCEMENT AND REPRODUCTION ENGINEERING

NEW YORK, 37 W. 65 St., 23 • SAN FRANCISCO, 1050 Howard St., 3 • LOS ANGELES, 1000 N. Seward St., 38

LEWIS WINNER, Editor

F. WALEN, Assistant Editor

We See...

SOME SIGNIFICANT CHANGES IN THE BROADCAST station allocation pattern are scheduled to be made when the clear-channel hearings enter their final stage in July. The plan to introduce station duplication at 750-mile intervals and reduce the number of 1-A clear-channel stations to about a dozen with powers remaining at 50 kw, will receive a real test during the hearings. Engineering survey data are now being prepared by Government and industry to show the geographical possibilities of relocation, area conductivity characteristics, population factors, and frequencies available. Optimum service for sparsely settled rural and remote areas will be a dominant factor in the reshuffling discussion.

In determining service and interference problems, a new procedure of study will be followed. The methods involve consideration of . . . variation of the atmospheric noise interference with time of day, geographical location and frequency of station being interfered with; and variation, with geographical latitude, in nighttime skywave transmission, for skywave service and for interference from skywaves. The signal level relative to interferences of various types will be considered in this study.

Another major clear-channel factor that will be considered will be f-m's position as a service. Many have indicated that f-m may replace regional and local a-m stations and that the a-m channels used for these services should be made available for clear or semi-clear channels to further serve rural areas with a skywave service. In a plan submitted by CBS, a 200 station f-m network was proposed. This network would cover 90% of the country, within a 50-microvolt contour, according to CBS. For the remaining 10% of the population, CBS proposed two 1,000-kw a-m stations operating at around 1,000 kc. Suggested locations were eastern Colorado and northern Kentucky.

Other a-m/f-m station arrangements and the corresponding use of variable powers will be considered, too, during the hearings.

It appears as if July will be a momentous month for the broadcast industry.

THE CLOSE RELATIONSHIP OF ENGINEERING EFFORT and industry profit was sharply analyzed by Dr. W. R. G. Baker recently during the first annual meeting of the RMA transmitter section. Describing the absolute end-result of engineering effort, Dr. Baker said that some say the end result is to create service for mankind, while others call it creative effort. But, said Dr. Baker, engineering has only one end-objective, and that is to make profit for someone.

It's up to the engineering profession, engineers as individuals, and engineers as groups he said, to provide the brain power, ingenuity and inventiveness to produce tools, processes, products and mechanisms whereby a substantial return may be earned. This, he emphasized, is the basic responsibility of the engineer in modern business today!—L. W.

COMMUNICATIONS

Including Television Engineering, Radio Engineering, Communication & Broadcast Engineering, The Broadcast Engineer. Registered U. S. Patent Office.
Member of Audit Bureau of Circulations.

MAY, 1946

VOLUME 26 NUMBER 5

COVER ILLUSTRATION

Measuring antenna radiation patterns with a model airplane and a miniature microwave antenna setup at the Ohio State University Research Foundation. (*Technique was described by George Sinclair at the IRE Winter Convention; see report in February* COMMUNICATIONS).

Published Monthly by the Bryan Davis Publishing Co., Inc.

BRYAN S. DAVIS, President **F. WALEN, Secretary**

PAUL S. WEIL, Vice Pres.-Gen. Mgr. **A. GOEBEL, Circulation Mgr.**

Advertising and Editorial offices, 52 Vanderbilt Ave., New York 17, N. Y. Telephone, MUrray Hill 4-0170. Cleveland 6, Ohio: James C. Munn, 10515 Wilbur Ave.; Telephone, SWeetbriar 0052. Pacific Coast Representative: Brand & Brand, 1052 W. Sixth St., Los Angeles 14, Calif.; Telephone, Michigan 1732. Wellington, New Zealand: Te Aro Book Depot. Melbourne, Australia: McGill's Agency.

Entered as second-class matter Oct. 1, 1937, at the Post Office at New York, N. Y., under the act of March 3, 1879. Yearly subscription rate: $2.00 in the United States and Canada; $3.00 in foreign countries. Single copies, twenty-five cents in United States and Canada; thirty-five cents in foreign countries.

For the Man Who Takes Pride in His Work

MODEL 2432 SIGNAL GENERATOR

Another member of the Triplett Square Line of matched units this signal generator embodies features normally found only in "custom priced" laboratory models.

FREQUENCY COVERAGE—Continuous and overlapping 75 KC to 50 MC. Six bands. All fundamentals. **TURRET TYPE COIL ASSEMBLY**—Six-position turret type coil switching with complete shielding. Coil assembly rotates inside a copper-plated steel shield. **ATTENUATION**—Individually shielded and adjustable, by fine and course controls, to zero for all practical purposes. **STABILITY**—Greatly increased by use of air trimmer capacitors, electron coupled oscillator circuit, and permeability adjusted coils. **INTERNAL MODULATION**—Approximately 30% at 400 cycles. **POWER SUPPLY** — 115 Volts, 50-60 cycles A.C. Voltage regulated for increased oscillator stability. **CASE**—Heavy metal with tan and brown hammered enamel finish.

There are many other features in this beautiful model of equal interest to the man who takes pride in his work.

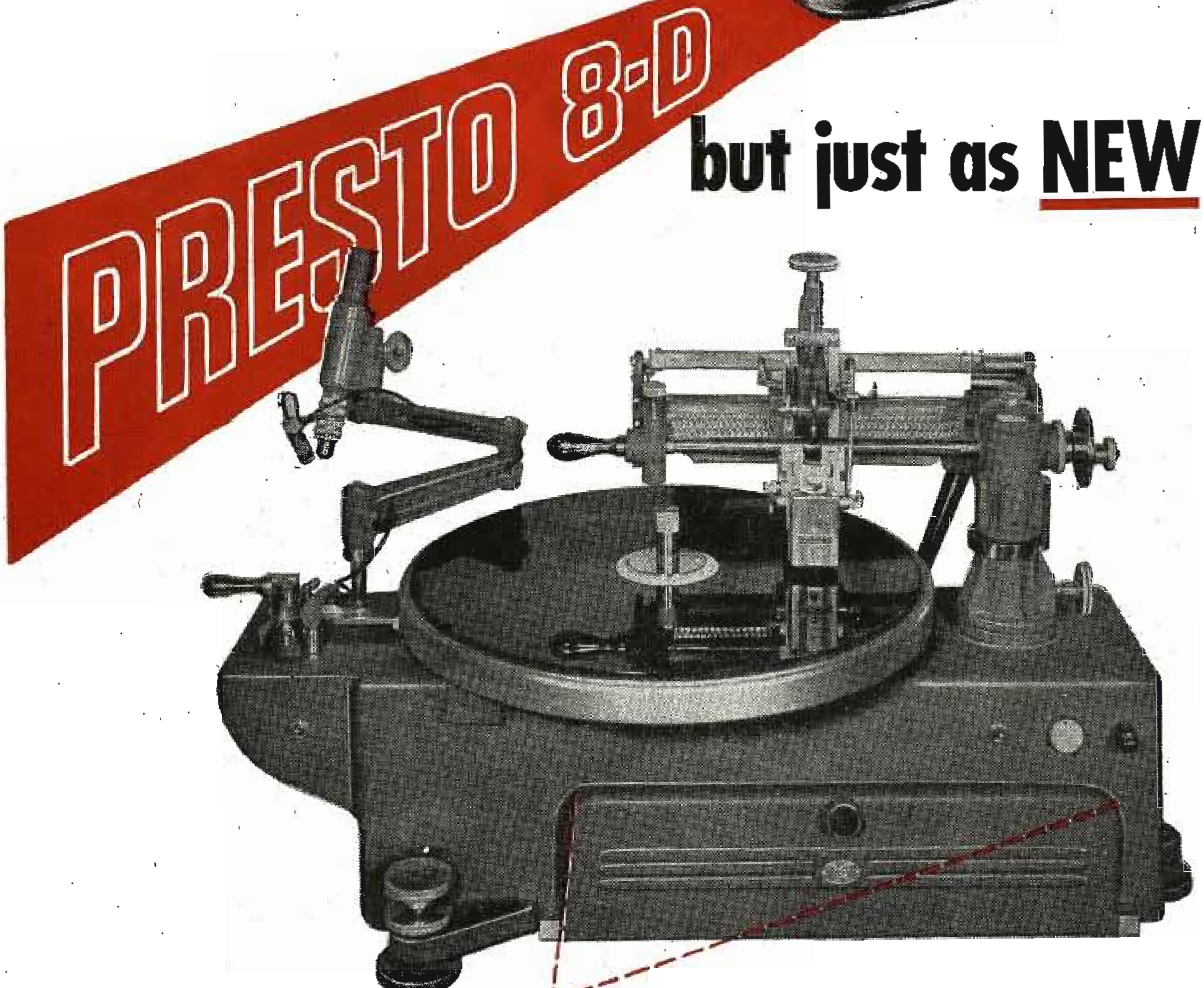
Precision first ...to last

Triplett

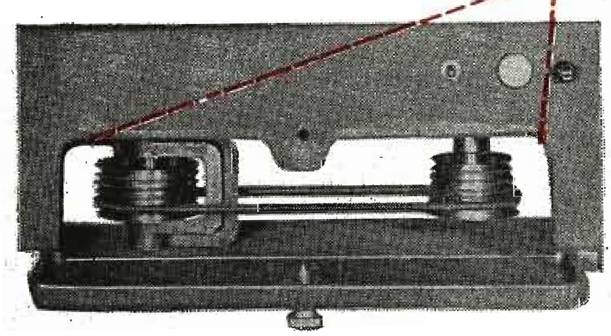
ELECTRICAL INSTRUMENT CO. BLUFFTON, OHIO

STANDARDS ARE SET BY TRIPLETT

Not jet propelled...



but just as NEW!



The belt on step pulleys slips instantly to any position to set cutting pitch at 96-104-112-120-128 or 136 lines per inch. Other pitches available on special order.

PRESTO'S newest *turntable* . . . for highest quality master or instantaneous recordings. The 8-D features instantaneous change of cutting pitch. An improved cutting head provides higher modulation level, more uniform frequency response and retains its calibration under all normal temperature conditions.

The heavy cast-iron turntable and mounting base insure exceptionally low background noise. Adjustable feet permit accurate leveling on bench or stand at a height to suit the operator.

PRESTO

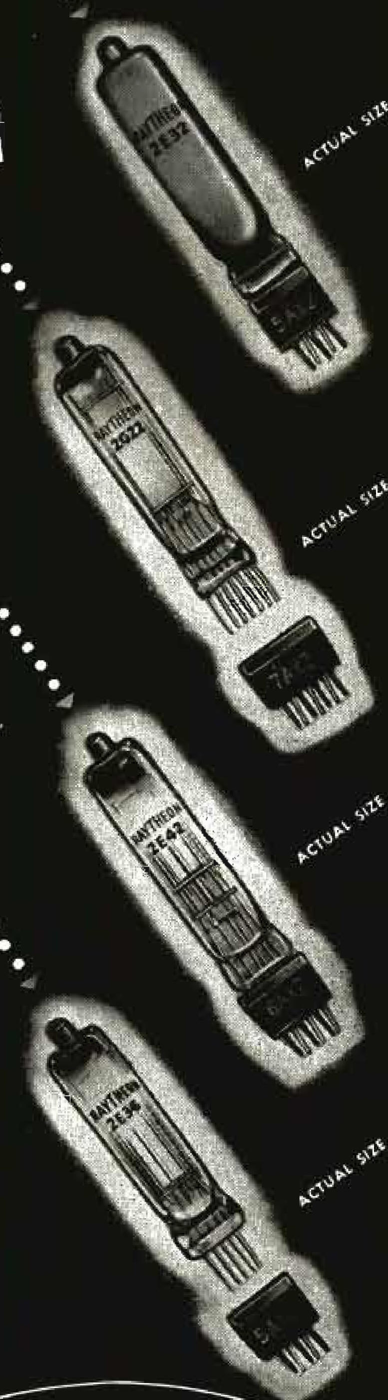
RECORDING CORPORATION

242 West 55th Street, New York 19, N. Y.

WALTER P. DOWNS, Ltd., in Canada

WORLD'S LARGEST MANUFACTURER OF INSTANTANEOUS SOUND RECORDING EQUIPMENT AND DISCS

NEW RAYTHEON SUB-MINIATURE TUBES for Pocket Receivers



Since 1938 Raytheon has pioneered in the design, development and production of small, low drain, long life tubes. These have helped to make possible the modern extremely compact hearing aid.

Now for Radio Receivers—Now Raytheon announces a physically similar kit of flat style, sub-miniature tubes for radio receiver applications. Included is a shielded RF-pentode amplifier, a triode-heptode converter, a diode-pentode detector-amplifier and an output pentode for earphone operation.

Much Smaller Radios Possible—These tubes make it possible to construct radios a fraction the size of prewar "personals," with sensitivity rivaling much larger sets.

The ratio of performance to battery drain is maintained very high, thus assuring the maximum possible operating life from the small size batteries now available.

The line consists of tubes approximately 1 9/16" long x 0.3" x 0.4" in cross section. Each type is available with pins for use with small commercially available sockets as illustrated, or may be had with long flexible leads for wiring the tube directly into the circuit.

No progressive radio manufacturer will overlook the tremendous possibilities inherent in the small pocket receiver—built around the new Raytheon sub-miniature tubes. But call on Raytheon for *every* tube need—large or small—for the finest in engineering, production and performance.

ELECTRICAL CHARACTERISTICS

	2E31† 2E32# Shielded RF Pentode	2G21† 2G22# Triode-Heptode	2E41† 2E42# Diode-Pentode	2E35† 2E36# Output Pentode
Filament Voltage	1.25 V	1.25 V	1.25 V	1.25 V
Filament Current	50 ma	50 ma	30 ma	30 ma
Max. Grid-Plate Capacitance	0.018 µµf	0.065 µµf‡	0.10 µµf	0.2 µµf
Plate Voltage**	22.5 V	22.5 V	22.5 V	22.5 V
Screen Voltage	22.5 V	22.5 V	22.5 V	22.5 V
Control Grid Voltage*	0	0	0	0
Osc. Plate Voltage	—	22.5 V	—	—
Plate Current	0.35 ma	0.2 ma	0.4 ma	0.27 ma
Screen Current	0.3 ma	0.3 ma	0.15 ma	0.07 ma
Osc. Plate Current	—	1.0 ma	—	—
Transconductance	500 µmhos	60 µmhos (Gc)	400 µmhos	385 µmhos
Plate Resistance	0.35 meg	0.5 meg##	0.25 meg	0.22 meg

*With 5 megohm grid resistance connected to F−.
**Higher voltage operation is possible as shown on engineering characteristics sheet available by request.
†Flexible lead Types.
#Plug-In Types.
##Approximate conversion Rp.
‡Signal grid to mixer plate Capacitance

RAYTHEON
MANUFACTURING COMPANY

Radio Receiving Tube Division

NEWTON, MASSACHUSETTS • LOS ANGELES
NEW YORK • CHICAGO • ATLANTA

EXCELLENCE IN ELECTRONICS

Collins 26W-1 Limiting Amplifier

Collins Speech Equipment

provides better program transmission and stronger signals

THE COLLINS 26W-1 audio limiting amplifier is a product of the most advanced standards of broadcast engineering. It effectively raises the modulation level, yet prevents overmodulation of the r-f carrier. The resulting stronger signal assists materially in station area coverage.

Developed for high fidelity AM and FM applications, the 26W-1 has a frequency response flat from 30-15,000 cps, with a variation of less than 1.0 db. The compression ratio above the verge of compression is 20/1 in db. Harmonic and tone distortion are not more than 1.5% at any frequency, any setting of the input and output levels, and with any amount of compression up to 15 db. Hum and noise are 70 db below the operating level. Output range is —4 to +26 dbm.

Complete metering provides measuring facilities for individual tube currents, plate voltage, compression level, and output level. Inside-out chassis construction gives immediate access to all wiring and circuit components upon removal of the slip-on dust cover. Operate and release times are independently adjustable.

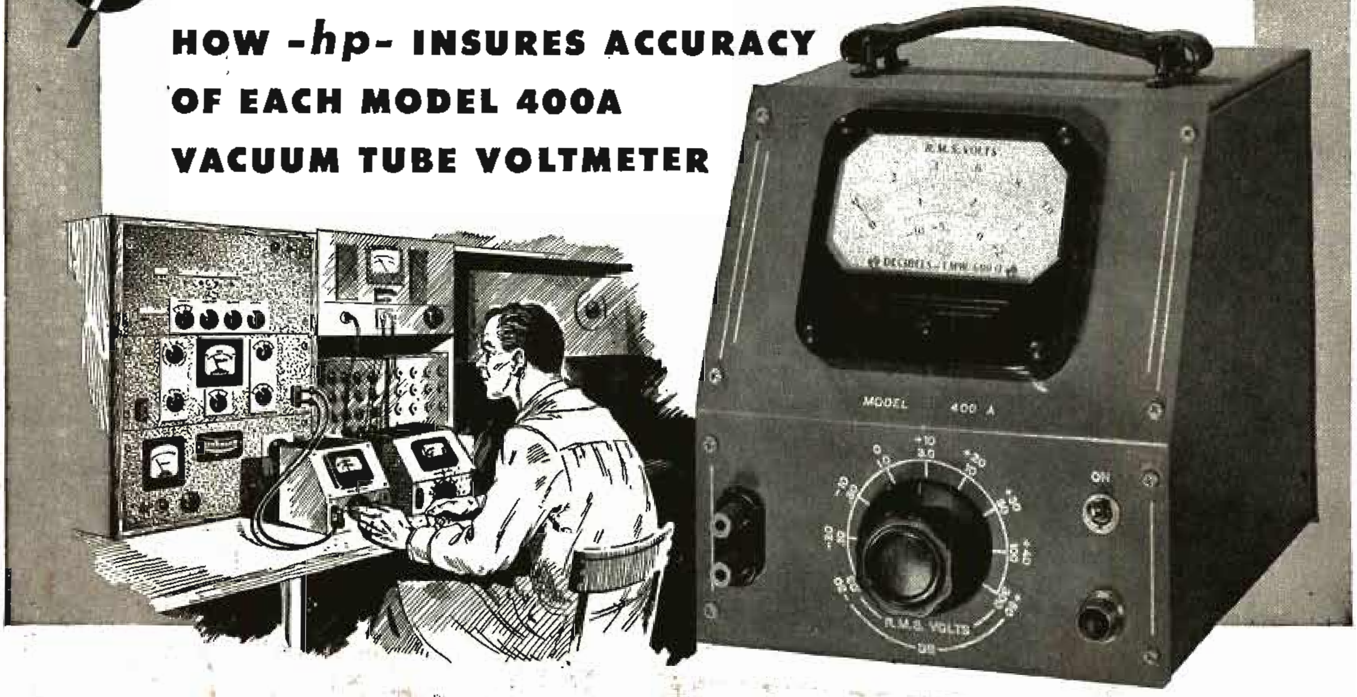
Dimensions, for standard rack mounting, 19″ w, 14″ h, 9″ d. Weight, 45 pounds. Available in metallic gray or black wrinkle.

Collins speech equipment is thoroughly engineered for highest performance. Reliable in operation, accessible in maintenance, each unit meets rigid inspection and tests before it is approved for delivery. For your requirements, write today to the Collins Radio Company, Cedar Rapids, Iowa; 11 West 42nd Street, New York 18, N. Y.

FOR BROADCAST QUALITY, IT'S . . . COLLINS

LABORATORY INSTRUMENTS FOR SPEED AND ACCURACY

HOW -*hp*- INSURES ACCURACY OF EACH MODEL 400A VACUUM TUBE VOLTMETER



The accuracy of -*hp*- instruments begins with the engineers' blueprints, but it does not stop there. Precision assembly, individual hand calibration for each instrument, and pre-calibration tests over the entire range of the instrument are your assurance that speed and accuracy will be maintained under all operating conditions.

UNIQUE VOLTAGE GENERATOR

Take the -*hp*- Model 400A Vacuum Tube Voltmeter for example. This measuring instrument is unusually versatile, because of its wide frequency range, wide voltage range, and high order of accuracy. For adequate production tests of the 400A, it was necessary to develop known voltages ranging from 3 millivolts to 300 volts, at frequencies from 10 cycles to 1,000,000 cycles. HP engineers solved the problem by building a unique voltage generator which would function as a test set by generating known voltages over the entire range of the Model 400A. Circuits were devised to develop 160 different combinations of voltages and frequencies, each a separate calibration point for the 400A. Each of these voltages is related to the other with an accuracy of better than ½%. The absolute magnitude of each voltage is held to better than ±1%. This voltage is compared regularly with standard laboratory instruments of high accuracy. The voltages which are developed are sinusoidal so that no error in calibration is introduced by poor wave form.

DEPENDABLE ACCURACY

Because of this careful checking and rechecking, you can depend on the operating efficiency and accuracy of the Model 400A Vacuum Tube Voltmeter for many measuring jobs, including measuring voltages in the audio, supersonic, and lower rf regions; amplifier gain; network response; output level; hum level; power circuit, high frequency, video, and carrier current voltages; capacity; and coil figure of merit. An outstanding feature of the -*hp*- Model 400A is that voltage indication is proportional to average value of the full wave.

For complete data on the Model 400A, and on other -*hp*- laboratory instruments, write today to Hewlett-Packard Company.

These -hp- Representatives Are at Your Service

Eastern Representative:
Burlingame Associates, Ltd.
11 Park Place
New York 7, N. Y.—Worth 2-2171

Midwestern Representative:
Alfred Crossley
549 West Randolph Street
Chicago 6, Illinois—State 7444

Western Representative:
Norman B. Neely Enterprises
7422 Melrose Avenue
Hollywood 46, California—Whitney 1147

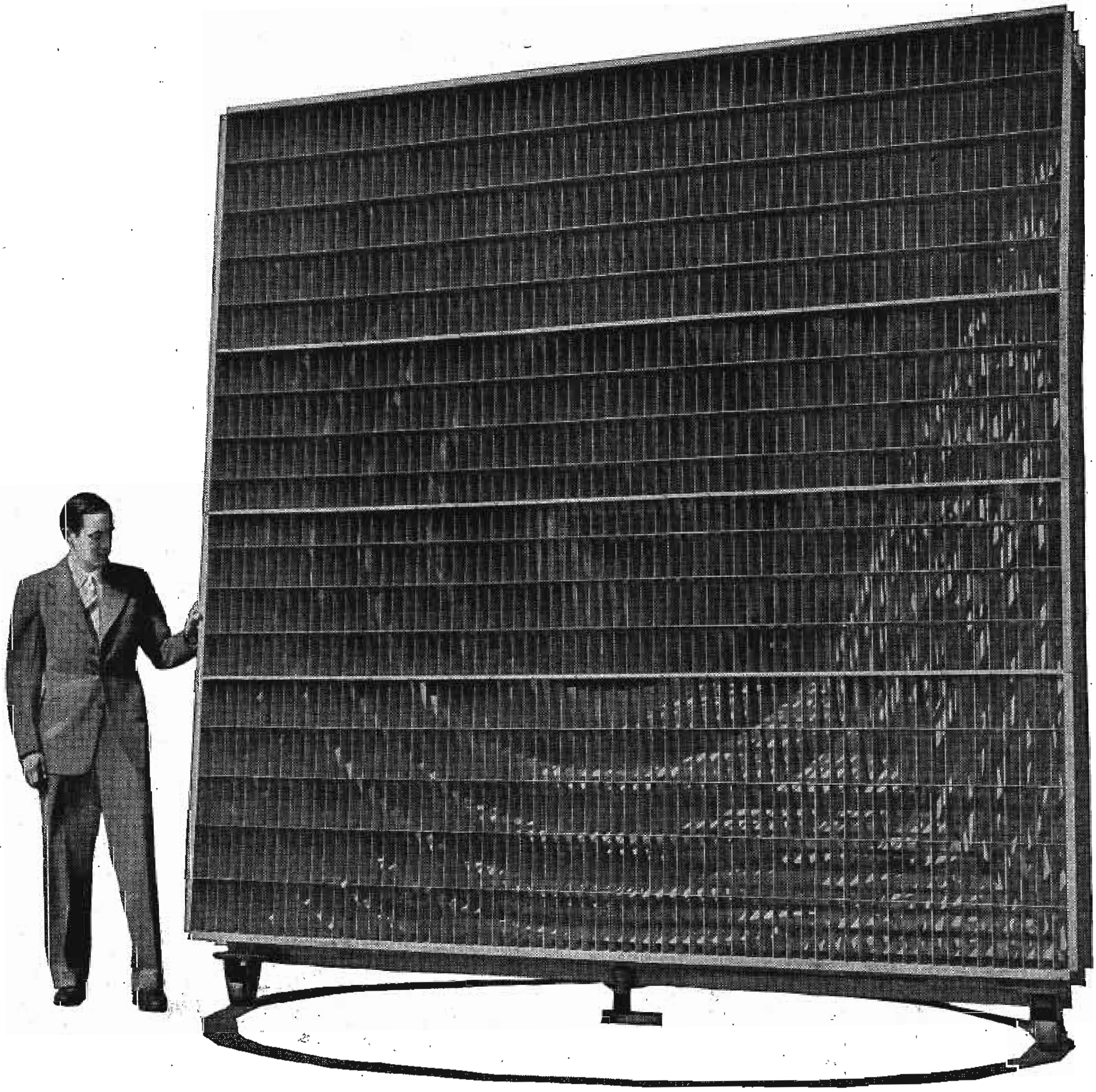
Canadian Representative:
Atlas Radio Corporation
560 King Street West
Toronto 2, Canada—Wa 4761

HEWLETT-PACKARD COMPANY

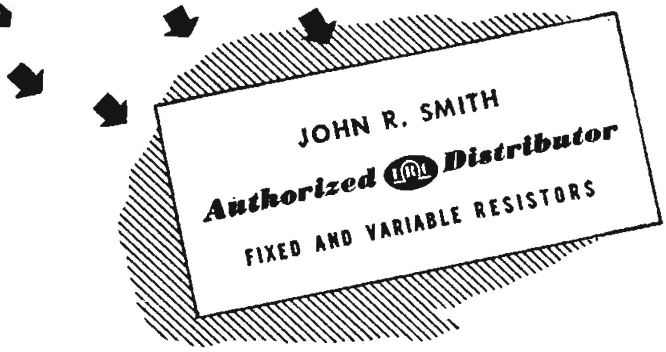
BOX 1199E • STATION A • PALO ALTO, CALIFORNIA

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

1199



THE MAN TO KNOW...



. . . when you need resistors in a hurry ! ! !

IRC distributors always have been valuable supplementary sources of supply to manufacturers of electronic and industrial equipment. During the war, they established an unusual record of service to manufacturers. IRC's more than 300 Authorized Distributors have proved themselves to be of the highest caliber, with exceptional organizations and facilities.

Under the newly-announced IRC Industrial Service Plan, these men are better prepared than ever before to give industrial users of resistance units prompt, intelligent and complete service on all IRC standard products, listed in IRC Catalog #50. They are rapidly gearing to maintain adequate stocks of the most widely-used IRC resistors and their sales forces are conversant with electronic requirements.

When you need resistors in moderate quantities for experimental work, pre-production models, pilot runs, small production runs, and for service and maintenance—it will pay you to call upon your local IRC distributor. We shall be glad to furnish his name upon request.

Write to Dept. 8-E for IRC Catalog #50 and names of local IRC Distributors.

PREFERRED FOR PERFORMANCE • IRC • FIXED & VARIABLE RESISTORS

INTERNATIONAL RESISTANCE CO.

401 N. BROAD ST.
PHILADELPHIA 8, PA.

Canadian Licensee:
International Resistance Co., Ltd., Toronto

FOR BETTER-THAN-STANDARD QUALITY . . . *Standardize on IRC*

NOW! FM

WTMJ—The Milwaukee Journal Station, Milwaukee, Wis., ordered this new Federal 8 Square-Loop Antenna with a 540 foot self-supporting tower, for immediate delivery.

PARTIAL TECHNICAL DATA

- Engineered for FM broadcast stations operating on an 88 to 108 mc. carrier.
- Loops are approximately 4½ feet square.
- Coaxially-fed loops concentrate radiated power in every direction of the *horizontal* plane.
- 8 loops are spaced 9 feet 3 inches apart on square supporting tower.
- Lattice-type steel supporting tower is two-feet square, and 74 feet high. It mounts a standard aviation safety beacon on top.
- Pyramidal, bridge-construction steel base optional to height desired.
- Designed to handle 10KW, 20KW and 50KW transmitters with effective radiated power outputs of 90KW, 180KW and 450KW respectively.

Federal

Export Distributor:
International Standard Electric Corporation

ANTENNA WITH NOMINAL POWER GAIN OF 9!

FEDERAL's 8 SQUARE-LOOP ANTENNA PROVIDES 90KW EFFECTIVE POWER OUTPUT WITH A 10KW TRANSMITTER... 180KW WITH A 20KW TRANSMITTER...450KW WITH A 50KW TRANSMITTER!

HERE IS STILL ANOTHER EXAMPLE of Federal's leadership in the entire field of FM ... an 8-loop antenna with the highest power gain ever available in the FM broadcast service.

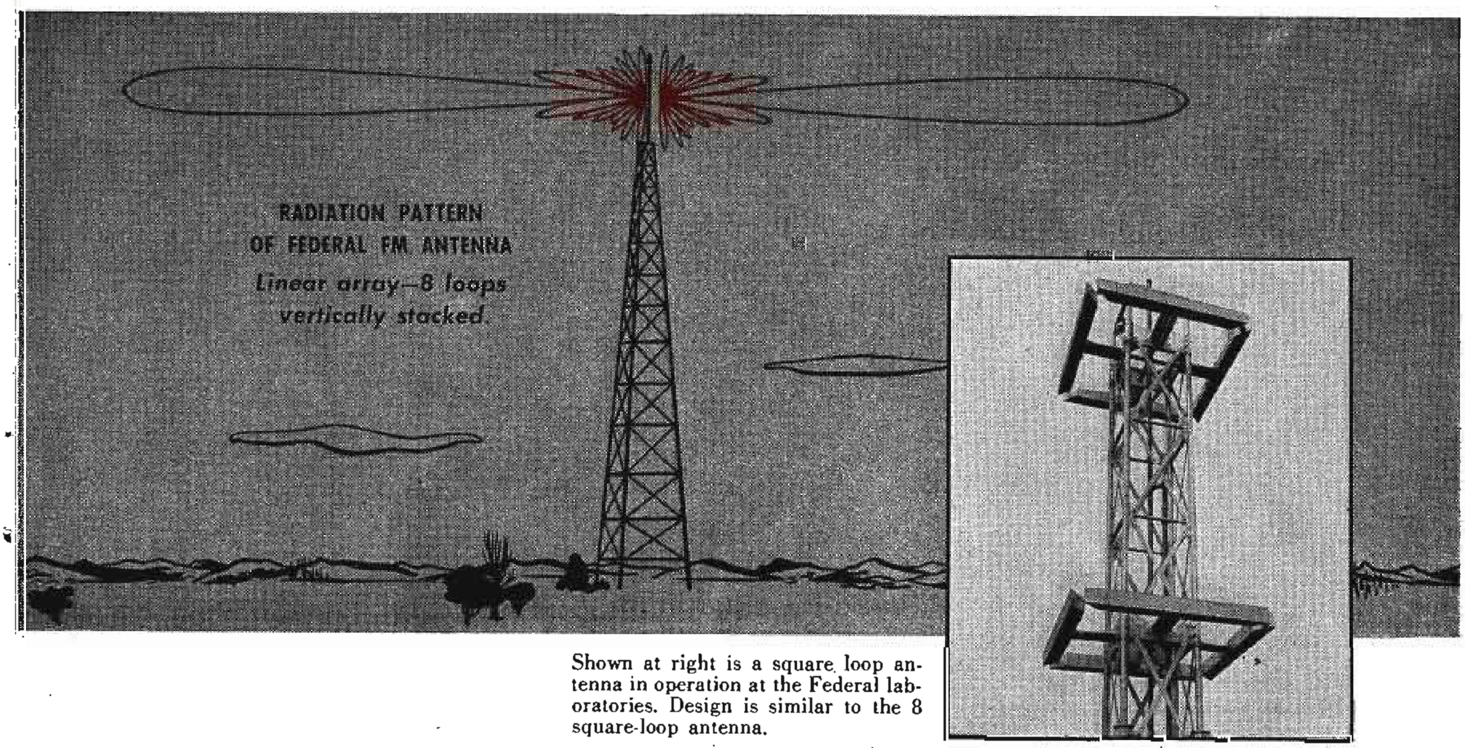
It radiates horizontally polarized waves so highly directive that very little energy is lost to useless ground or sky wave. Thus, with a power gain of 9, you can now get an effective power output of *90KW with a 10KW transmitter; 180KW with a 20KW transmitter and 450KW with a 50KW transmitter!* This not only means a great saving on the cost of original equipment, but important economies of operation as well.

Be prepared for future FCC action increasing the effective radiated power!

One antenna is built for use over the entire FM range ... 88 to 108 megacycles. Only one predetermined stub adjustment per loop changes it for any frequency in this band. Also, antenna array may be fed in two sections with separate coaxial lines to allow for emergency auxiliary operation.

Structurally, the tower is designed not to disturb the circular pattern of the antenna's radiation ... is supported on a rugged, pyramidal base. The entire unit withstands high wind velocities and heavy icing loads.

Coming at a time when the FCC has given the green light to FM station construction, this remarkable new antenna is another contribution to the advancement of FM transmission ... part of the "completely packaged service" which Federal now makes available. A Federal engineer will be glad to give you full details.



Shown at right is a square loop antenna in operation at the Federal laboratories. Design is similar to the 8 square-loop antenna.

Telephone and Radio Corporation

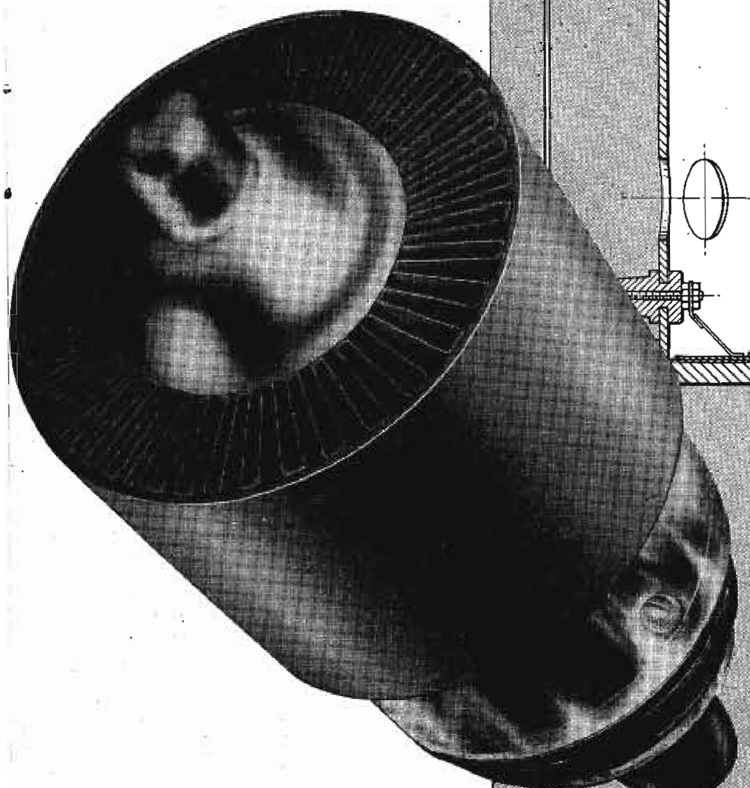
Newark 1, New Jersey

AN IT&T ASSOCIATE

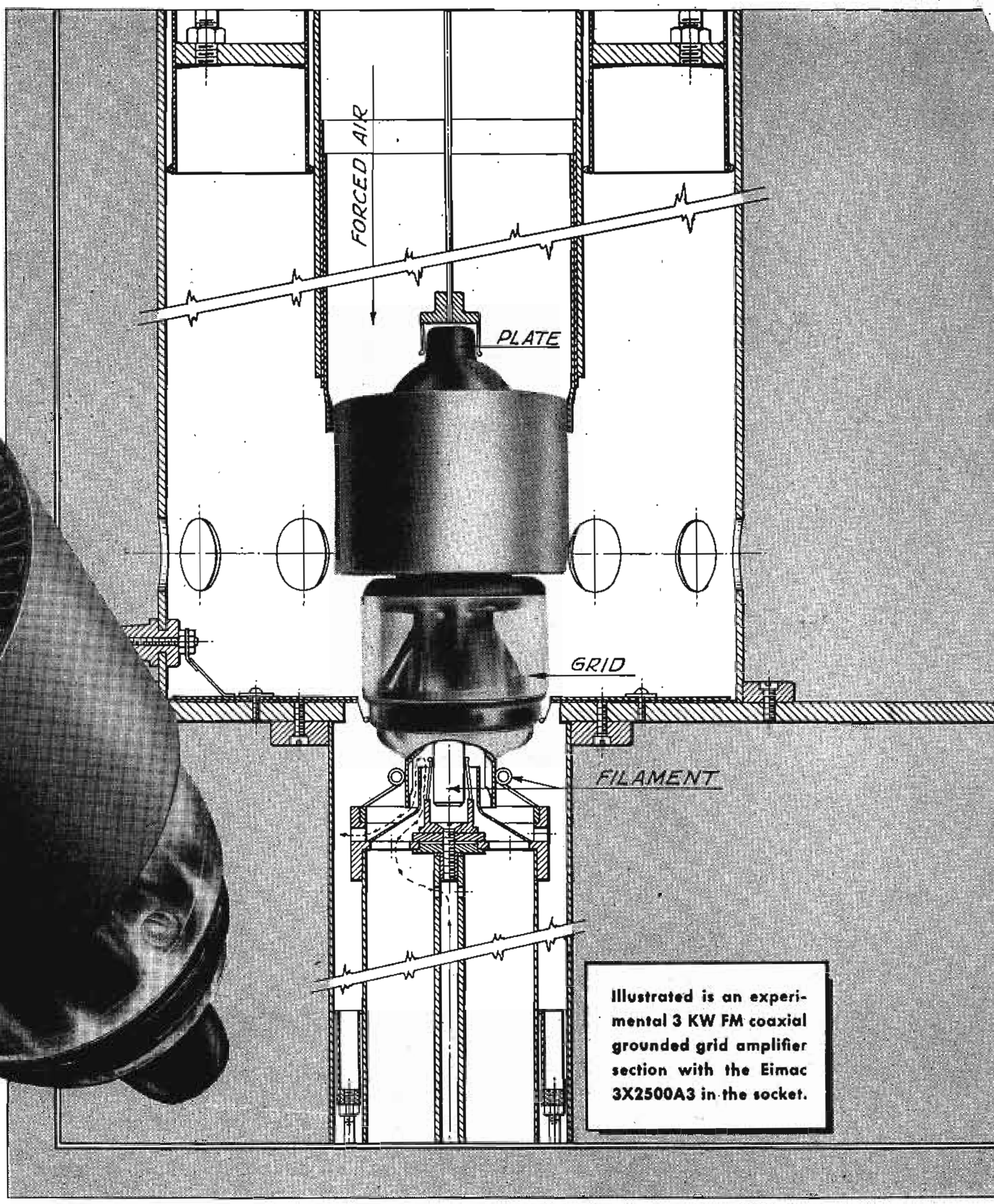
FEDERAL TELEPHONE & RADIO FTR

Eimac TUBES

THE COUNTERSIGN OF DEPENDABILITY IN ANY ELECTRONIC EQUIPMENT



EIMAC 3X2500A3



Illustrated is an experimental 3 KW FM coaxial grounded grid amplifier section with the Eimac 3X2500A3 in the socket.

READY FOR FM *NOW*

3500 watts (useful*) output at 88 to 108 mc

The radical and efficient mechanical design of this new Eimac external anode triode makes it ideal for use in any type transmitter circuit. For example, note in the illustration above how well the arrangement of the terminals enables it to fit into a grounded grid amplifier. Its design features will be very much appreciated in the efficient layout of FM transmitters—grounded grid or neutralized. In typical grounded grid operation at 110 mc, the Eimac 3X2500A3 will provide 3½ KW of useful* output with only 3000 volts on the plate. Furthermore, only 800 watts (approx.) of driving power are required for such operation. To get your FM transmitter on the air quickly and efficiently, use the new Eimac 3X2500A3 tube—tried and proven for the job. Complete technical data is available now. 1151

* *Power actually delivered to the load.*

Typical Operation (110 mc., 1 tube)

D-C plate voltage	3000 volts
D-C plate current	1.6 amps.
D-C grid voltage	–350 volts
D-C grid current	250 ma.
Driving Power (Approx.)	800 watts
Plate dissipation (Approx.)	1500 watts
Total power output (Approx.)	3800 watts
Useful power output	3500 watts

CALL IN AN EIMAC REPRESENTATIVE FOR INFORMATION

ROYAL J. HIGGINS (W9AIO)...600 S. Michigan Ave., Room 818, Chicago 5, Illinois. Phone: Harrison 5948.

V. O. JENSEN, General Sales Co., 2616 Second Ave., Seattle 1, Washington. Phone: Elliott 6871.

M. B. PATTERSON (W5CI)...1124 Irwin-Kessler Bldg., Dallas 1, Texas. Phone: Central 5764.

ADOLPH SCHWARTZ (W2CN)...220 Broadway, Room 2210, New York 7, N.Y. Phone: Cortland 7-0011.

HERB BECKER (W6QD)...1406 S. Grand Ave., Los Angeles 15, California. Phone: Richmond 6191.

TIM COAKLEY (W1KKP)...11 Beacon Street, Boston 8, Massachusetts. Phone: Capitol 0050.

FOLLOW THE LEADERS TO

Eimac REG. U.S. PAT. OFF. TUBES

EITEL-McCULLOUGH, INC.
1151-H San Mateo Ave., San Bruno, Calif.
Plants located at: San Bruno, Calif. and Salt Lake City, Utah
Export Agents: Frazar & Hansen, 301 Clay St., San Francisco 11, Calif., U.S.A.

CAUTION!
Check serial numbers on Eimac tubes before you buy. Be sure you're getting newest types. Look for latest serial numbers.

SUPER PRO

Series 400

Less QRM---Phone or CW

When the bands are active it only takes one minute to find that you need Hammarlund's patented variable crystal filter to have a successful QSO—either phone or CW.

Look to the future! When the number of Hams doubles or trebles you will need the crystal filter that weeds-out the QRM . . . If you can't hear 'em, you can't work 'em!

Price (SP-400-X)
$342.00
Including Speaker

THE SIGN OF QUALITY
ESTABLISHED 1910

HAMMARLUND

THE HAMMARLUND MFG. CO., INC., 460 W. 34TH ST., NEW YORK 1, N.Y.
MANUFACTURERS OF PRECISION COMMUNICATIONS EQUIPMENT

COMMUNICATIONS

LEWIS WINNER, Editor

★ ★ MAY, 1946 ★ ★

Railroad F-M SATELLITE SYSTEM

by WILLIAM S. HALSTEAD

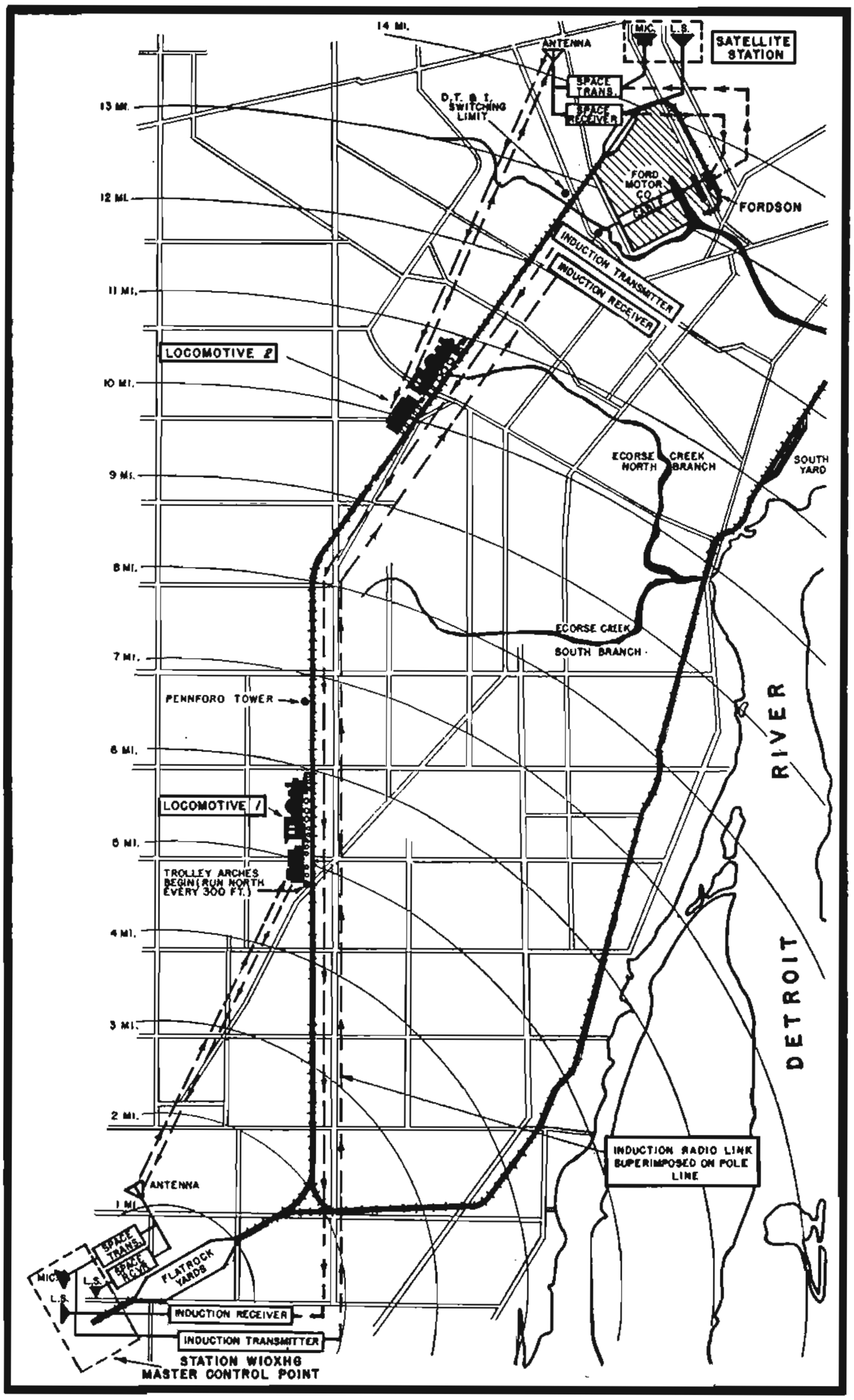
Consultant
Farnsworth Television and Radio Corp.

IN APPLYING V-H-F radiotelephone equipment to railroad service, experience has indicated that one of the primary requirements is the maintenance of thoroughly reliable, solid two-way communications between fixed stations and mobile units within their service areas.

Unlike other services in which an appreciable degree of signal-level variation or electrical noise may be tolerated, railroad conditions demand a strong voice signal of substantially constant acoustic level in the locomotive cab, caboose or other mobile unit at all times, regardless of the location of the mobile unit at a given moment.

Above. M. L. Bricker, Ford Motor Company operating vice president, broadcasting from the fixed f-m station in the DT&I Flat Rock Yards outside Detroit, Michigan, to one of the f-m mobile units during field tests. At left, main station induction unit; at right, space radio transmitting, receiving and power supply equipment, with speaker and control unit.

Ten-Watt F-M 161.775-mc Satellite Booster Station Operating in Conjunction with 189-kc F-M Induction System Provides Effective Station-to-Station Remote Control Service and Point-to-Train, Train-to-Train, Intra-Train and Point-to-Point Services.



Map of Detroit area covered during the DT and I tests. System provides: (*a*)—master control communication direct with locomotive *1*; (*b*)—master control communication through induction link and satellite space transmitter to locomotive *2*; (*c*), auxiliary-control point communication through satellite transmitter to locomotive 2, with induction link providing signal to master-control point for monitoring transmissions from satellite transmitter; and (*d*) direct communication from locomotive *1* to *2*, with transmissions being monitored by fixed stations.

Since engineers or conductors are usually occupied with duties which require their full attention, there is no opportunity for volume-control adjustments when ambient noise becomes excessively high, as often happens when two trains pass at high speed on adjacent tracks. This means that all voice signals, to be effective under varying conditions, must remain well above the noise normally found in rail service. Therefore a selected voice-reproduction level must be maintained without need for adjustment of controls by train personnel.

Studies of the performance of a-m and f-m equipment in railroad service have shown that, with f-m, an audio-frequency signal of substantially uniform level, free of *flutter* or other undesirable audio signal variations, may be obtained on mobile units and at fixed stations, once the threshold point of the receivers has been reached. With a-m equipment the received audio-signal level tends to decrease noticeably as the mobile units move away from the locality of the fixed stations. This requires a re-setting of the volume control of the a-m receivers, if the same audio signal level is to be maintained at the loudspeaker.

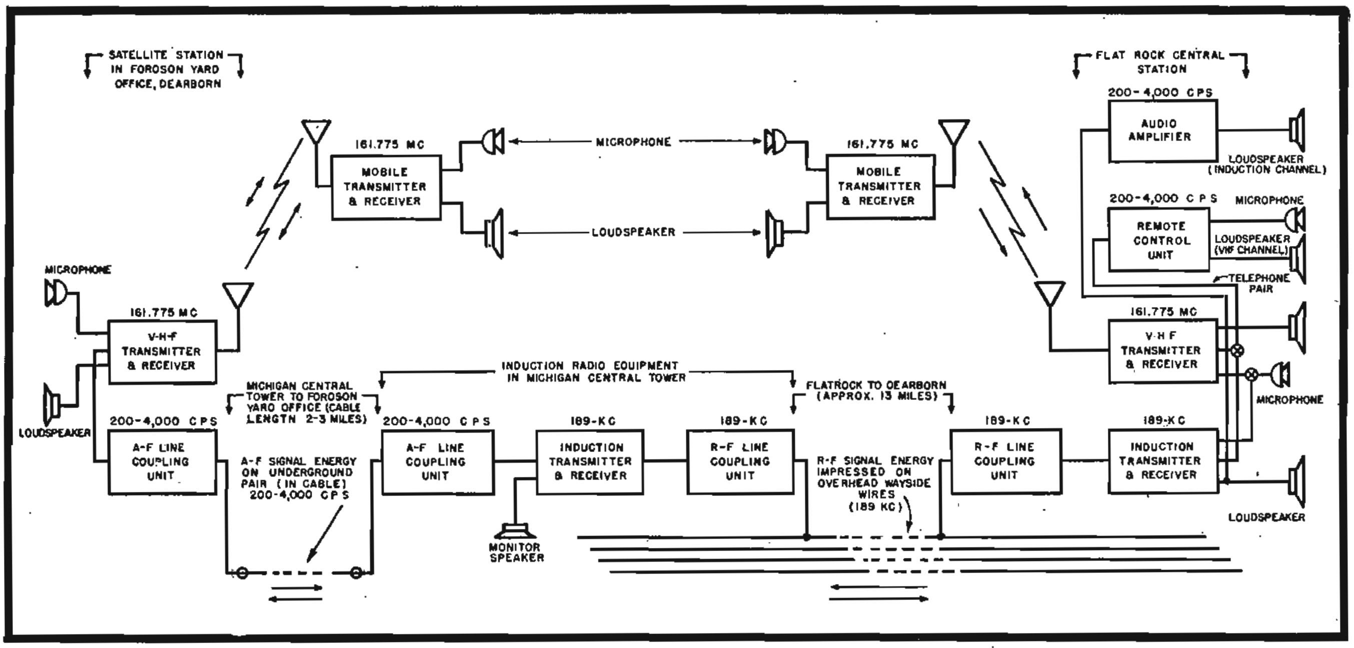
At v-h-f this problem is complicated by *flutter*, and by *radio shadow* effects which, in general, become more noticeable as the carrier frequency is increased. Thus, a train located in a localized *flutter* area, or beneath a steel structure, may temporarily be in a zone where reliable radio communications cannot be established, or where radio signals from a fixed station may not effectively be heard.

The use of f-m equipment also facilitates the maintenance of relatively high-signal intensity at all points along a railroad's right-of-way, since satellite or *booster* stations, operating on a common frequency, may be used at strategic points in different zones of a large service area. Co-channel satellites can operate two or more f-m fixed-stations on the same assigned carrier frequency, without objectionable heterodyne squeals. This provides an opportunity for establishment of higher r-f signal levels within the service areas of the respective stations, thereby raising the average field intensity at points where shadow effects or flutter would be obtained if only one fixed station were employed to serve a large area.

Satellite-System Tests

To obtain more specific information on satellite operation in railroad service on frequencies in the 152-162 megacycle band, and to determine the practicability of a satellite system in large industrial yard areas where shadow effects and flutter have been experienced, a series of tests with a new f-m satellite system were conducted. The tests were held on the Detroit, Toledo and Ironton railroad between Flat Rock, Michigan, and the Rouge River plant of the Ford Motor Company, at Dearborn, about 14 miles from Flat Rock. The program included point-to-train, train-to-train, intra-train, and point-to-point communications.

Two v-h-f fixed stations, in each of which a 10-watt f-m transmitter and associated receiver were employed, were installed for the experiment. The central station, W1OXHG, was located at the Flat Rock yard, with remote-control from the yardmaster's office. The transmitter and receiver tuned for



Block diagram of f-m satellite system for railroad radio service.

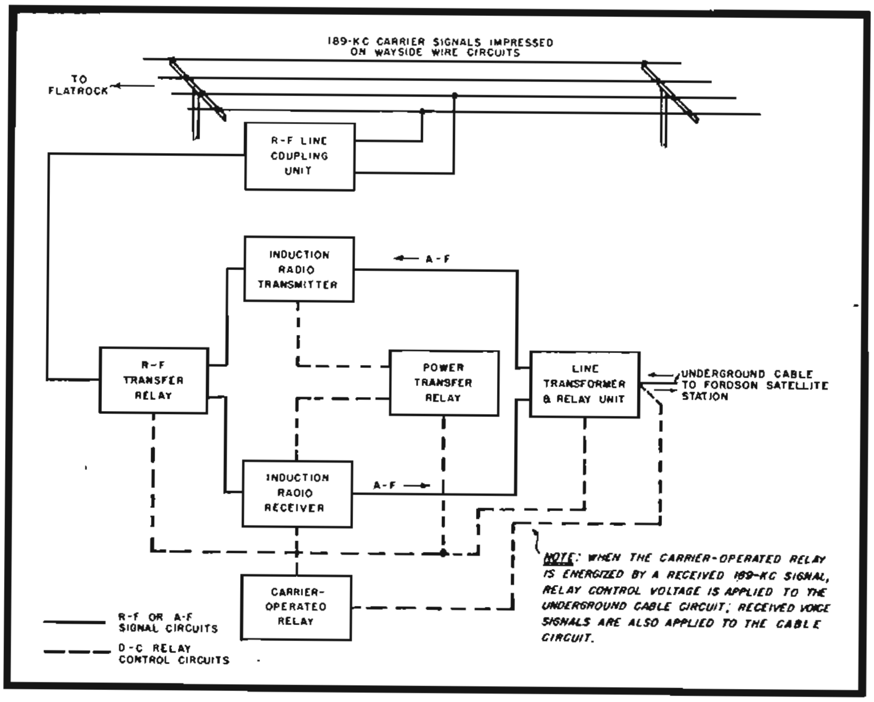
operation on a frequency of 161.775 mc, were housed in a small shanty adjacent to the base of a 150′ water tower, on the top of which a vertical radiator was mounted. Solid-dielectric transmission cable, of low-loss type, approximately 1″ in diameter, was used between the antenna and the radio equipment.

Remote-control of the v-h-f equipment was accomplished by means of a desk-mounted control unit at the yardmaster's office and an associated telephone line extending for a distance of approximately 1,000′ between the office and the radio shanty.

To extend the remote-control circuits from the Fat Rock yardmaster's office to a satellite station at the Fordson yard of the Ford Motor Company, about 14 miles away, an induction radio circuit of f-m type, was established in connection with already-existing wire lines extending along the DT&I railroad between Flat Rock and Dearborn. The induction equipment was utilized because there was no wire pair available for remote-control functions on the railroad-owned wire line circuit between Flat Rock and Dearborn. In addition, installation of a new wire line would have been time-consuming and involved an expense of many thousands of dollars. It was also indicated that the induction-radio inter-station link would be desirable for other reasons, including (*1*) relative freedom from control circuit failure in event of breaks in overhead wire circuits due to storms or other causes; (*2*) high signal-to-noise ratio obtained with f-m carrier equipment; (*3*) improved audio-frequency response of induction radio circuits as compared with ordinary wire telephone circuits; (*4*) possible utilization of the combined induction and radiation fields, which extend about the overhead wires, for reaching railroad personnel equipped with compact, light-weight induction radio rereceivers (or receiver-transmitter units); and (*5*) flexibility of the induction radio system in accommodating additional remote-control points, should they be desired at any location along the railroad's right-of-way.

An induction radio transmitter and associated receiver, operating on 189 kc, were installed next to the v-h-f space-radio equipment in the radio shanty at Flat Rock. Carrier energy at 189 kc was impressed on a telephone pair by means of series capacitors, and then by induction impressed on all the wayside wires of the DT&I pole line between Flat Rock and Dearborn. The induction transmitter at Flat Rock was provided with an r-f attenuator, which served to reduce the amount of r-f power impressed on the wire line to about ½-watt. This was sufficient to provide a strong carrier signal at an induction receiver located in the Dearborn area, at a distance of about 13 miles from Flat Rock. Remote control of the induction transmitter was accomplished by means of the same control unit employed with the v-h-f equipment, with a simple selector switch and relay connection being used to effect change from local v-h-f control to remote-control of both the v-h-f satellite

E. A. Nicholas, seated, president of Farnsworth and M. L. Bricker at the remote-control unit in the yardmaster's office of the Flat Rock yards.



Block diagram of induction radio control circuits at Michigan Central Tower.

and the local v-h-f transmitter. This made possible the use of the same microphone and amplifier at the yardmaster's office for both local and remote-control operations. A monitor amplifier and loudspeaker were employed in connection with the output circuit of the induction receiver, with a separate audio line being used for the monitoring circuit. This permitted individual monitoring of the local v-h-f receiver, and the satellite v-h-f receiver via the induction radio link.

An induction transmitter and receiver similar to that employed at Flat Rock were coupled to the DT&I wayside wire circuits at a point near the boundary of the Ford Motor Company's plant at Dearborn, about 13 miles northeast of Flat Rock. Capacitive coupling to two of the overhead wires on the pole line was employed, as in the arrangement at Flat Rock.

The induction equipment was installed in a signal tower of the Michigan Central Railroad, which crossed the tracks of the DT&I Railroad at this location. An underground telephone circuit, extending between the Michigan Central tower and the Fordson yard office, about one airline-mile apart, was used as a link between the induction equipment at Dearborn and the v-h-f satellite station at Fordson yard. This underground circuit, consisting of a telephone pair, normally carried audio-frequency signals from the output of the induction receiver at the Michigan Central tower to the input circuit of the v-h-f satellite transmitter at Fordson yard. The same wire circuit also carried relay-control voltage, which was applied to the line during periods of reception of carrier wave energy from the Flat Rock induction transmitter. This was accomplished by means of a carrier operated relay in the induction receiver at the Michigan Central tower. At the v-h-f satellite station, the relay-control voltage was used to provide application of plate voltage to the v-h-f transmitter, and to effect transfer of the antenna from the v-h-f receiver to the v-h-f transmitter. In this manner, by means of the 189-kc induction-radio link, the yardmaster at Flat Rock was able to talk over the satellite transmitter at Fordson yard, with all remote-control functions centralized at the Flat Rock station.

During reception of a v-h-f signal from mobile units in the Fordson service area, a carrier-operated relay in the v-h-f receiver at the Fordson yard office applied control voltage to the underground telephone circuit and caused plate power to be applied to the induction transmitter at the Michigan Central tower. Carrier signals at 189 kc, modulated by the received v-h-f signals, thus were impressed on the wayside wire circuits, and received on the Flat Rock induction receiver and its associated monitor amplifier and loudspeaker in the Flat Rock yard office.

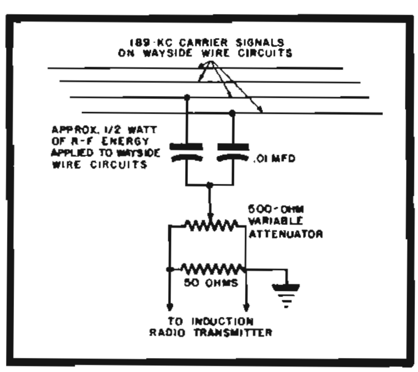
In this manner v-h-f signals at relatively high levels were provided at all points in the service areas of the Flat Rock Central station and the Fordson satellite, when comprehensive large-area coverage was desired. In the event that communications were desired only in the local Flat Rock service area, the v-h-f transmitter at Flat Rock was employed, and the satellite station was not used.

In addition to the provision of remote-control of the Fordson satellite transmitter from Flat Rock, a local control switch, microphone and loudspeaker were installed at the Fordson yard office for use by the yardmaster at the Fordson station. This enabled the yardmaster in the Ford plant area to establish local communications with mobile units in his service area.

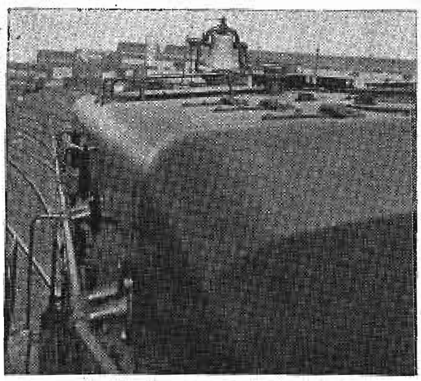
The v-h-f transmitter and receiver at the Fordson satellite station were similar to those used at Flat Rock. A vertical antenna, of the type employed at Flat Rock, was installed on a 75′ floodlight tower, with connection be-

William G. Clinton, DT&I communications engineer, showing induction unit to Emery Lee, FCC inspector.

Block diagram of r-f attenuator and line coupling unit employed in induction system.



Radio-equipped steam locomotive inside the Ford Motor Company's Rouge plant.



Low-clearance 11" *firecracker* type antenna on Diesel locomotive.

tween the antenna and the equipment in the yardmaster's office by means of a solid-dielectric coaxial transmission line.

Operational Characteristics of Equipment

All fixed-station equipment was operated from 115 volts, 60 cycles, on a press-to-talk simplex basis. An assigned carrier frequency of 161.775 mc was used by the Flat Rock and Fordson v-h-f stations. Crystal control of v-h-f transmitters and receivers was employed at each station, with a frequency stability of ±.005% or better being maintained under normal operating conditions. Frequency swing of the v-h-f transmitters was ± 15 kc during voice modulation. An audio-frequency peak limiting circuit was used in the transmitters to prevent excessive frequency deviation.

Sensitivity of the v-h-f receivers was approximately 0.5 microvolt for saturation of the limiter circuit. Selectivity was sufficient to provide a response at least 60 db down at 120 kc off resonance. The audio-frequency power output was approximately 5 watts, maximum.

The induction transmitters employed a reactance-tube modulator circuit, with direct frequency-modulation being obtained in the oscillator circuit. The frequency swing was approximately ± 4 kc during normal voice modulation. The effective audio-frequency range of this equipment extended from approximately 200 to 4,000 cycles. The radio-frequency tuning range was 150 to 250 kc. Frequency stability was 0.1% or better under normal operating conditions.

The induction receivers were of the tuned r-f type, with a sensitivity of approximately 10 microvolts for full saturation of the limiter circuit. Maximum power output was 5 watts. Response of the receiver was within ±3 db from 200 to 4,000 cycles; selectivity was adequate to provide a response at least 70 db down at 13 kc removed from the operating frequency.

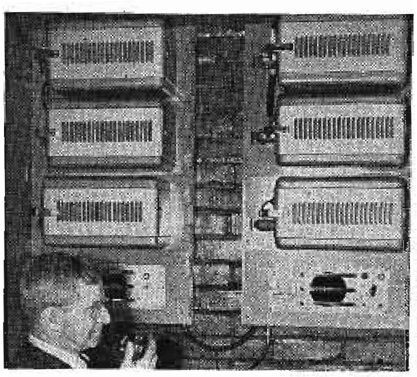
Locomotive Equipment

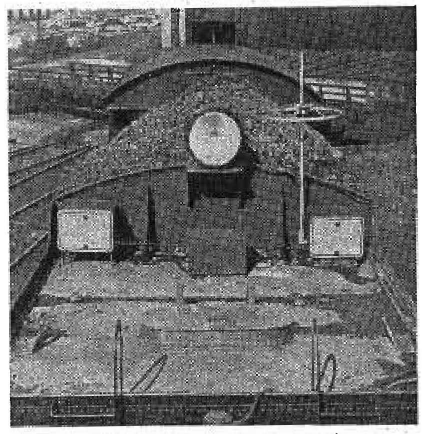
The radio equipment on each of the two locomotives employed during the tests consisted of a 10-watt v-h-f f-m transmitter and associated receiver, similar to those used at the fixed stations. Operation was on 161.775 mc.

One mobile installation, located on a steam locomotive, was powered by a 32-volt vibrator unit. This furnished 115 volts, 60 cycles for operation of the radio equipment through its associated 115-volt, 60-cycle power supply unit. The second mobile unit was mounted on a Diesel-electric locomotive. A 64-

(*Continued on page* 54)

Satellite space and induction equipment at the Ford Motor Company Rouge plant. Paul Cunningham, DT&I dispatcher, is at microphone.

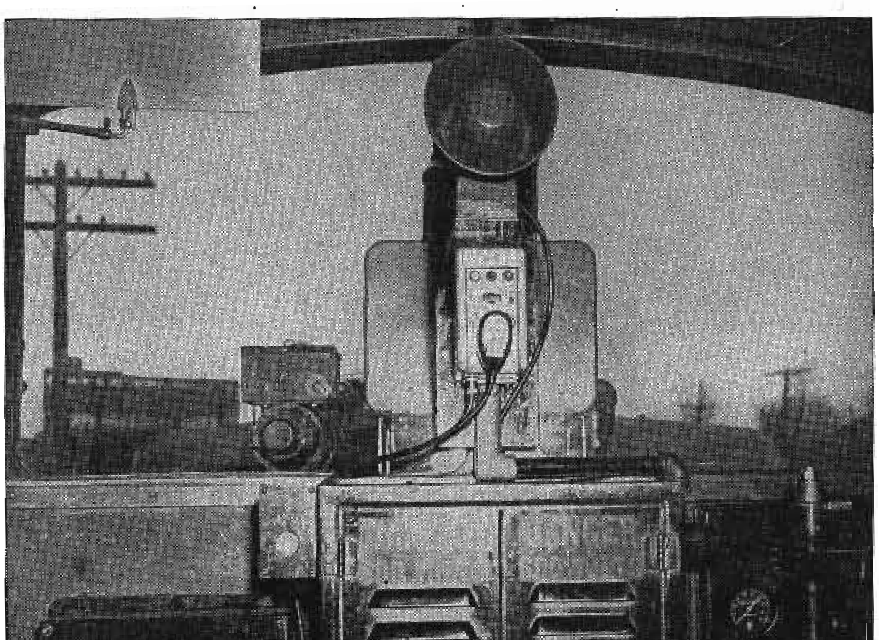




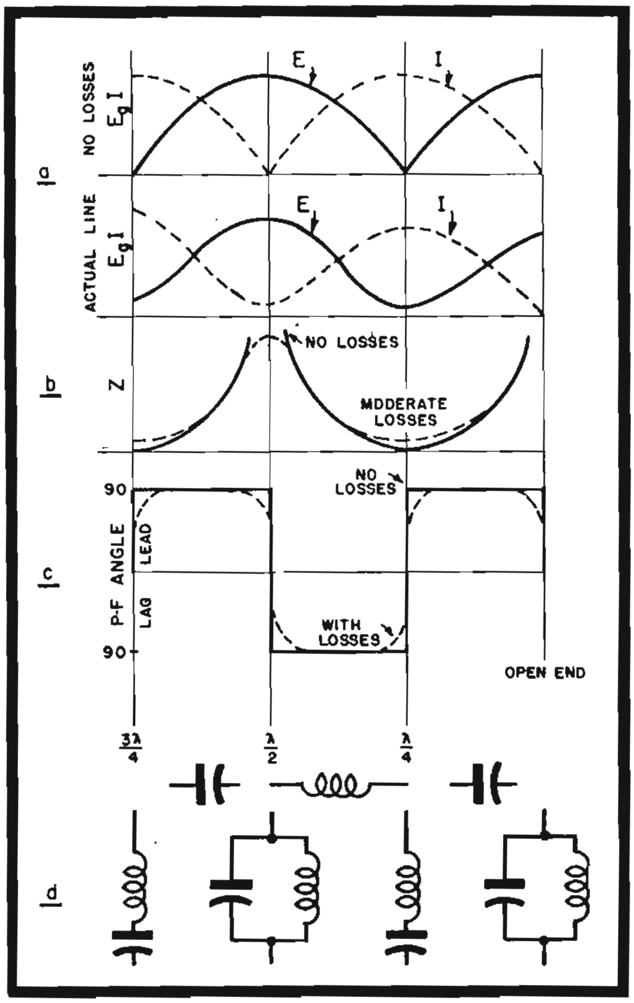
Installation of equipment on tender of steam locomotive. Outer housings, in which transmitter, receiver and power supply units are shock and vibration-mounted, are at either side of the tender, with the cartwheel type ground-plane mobile antenna at right.

Coach equipped with a remote-control unit providing monitoring of train-to-train, train-to-fixed-station, and intra-train communications. A. E. Curry, Farnsworth project engineer, is at microphone; H. M. Large, Pennsylvania Railroad Traffic Manager, at control box.

Remote-control unit with loudspeaker and dynamic microphone, inside a Diesel cab.



TRANSMISSION LINES as RESONANT CIRCUITS



by L. R. QUARLES

Associate Professor of Electrical Engineering, University of Virginia

Figure 1

Characteristics of the open line. In (*a*) we have the magnitude of the resultant voltage and current for a line without losses and a practical line with small losses. Impedance variations are shown in (*b*). In (*c*) appears the power factor angle. Circuits to which each point or section is equivalent are shown in (*d*).

In this, the first of a series of three papers, appears a discussion of open and shorted lines, lines as inductances, lines as resonant circuits and high-impedance quarter-wave lines.

At very high frequencies the construction of suitable coils and capacitors for resonant circuits becomes difficult and at s-h-f, construction becomes impossible. In this region it is then necessary to find some other means of obtaining resonant characteristics in circuits. When transmission lines are properly constructed they may be used to replace the more conventional circuit elements. In many cases, such lines have decided advantages over the ordinary components. The lines may be made to have inductive, capacitive, or resonant characteristics as desired by the choice of dimensions. It is fortunate that in the region where it becomes necessary to substitute for the usual coil and capacitor combinations, the physical dimensions of the transmission line substitutes are small enough to permit their use without complications.

If a wave is applied to a transmission line which is terminated in its characteristic impedance, there will be no reflection at the end, all the energy of the wave being absorbed in the terminating impedance. The current and voltage distribution along the line will be a smooth curve. However, if, instead of this characteristic impedance, the line is terminated in some other value, the wave will be reflected to some degree and we will no longer have a uniform distribution of current and voltage on the line.

Of particular interest are the special cases when the line is either short circuited or open at the end. Let us first examine the open line. When an alternating voltage is applied to such a line, voltage and current waves will progress down the line, but upon reaching the end both will be completely reflected. At this reflection the current wave is reversed in phase and the voltage is reflected without phase reversal. The resultant voltage or current on the line at any point is the vector sum of the proper initial and reflected waves. At the open end, the two voltage waves are in phase so they add to give a high voltage while

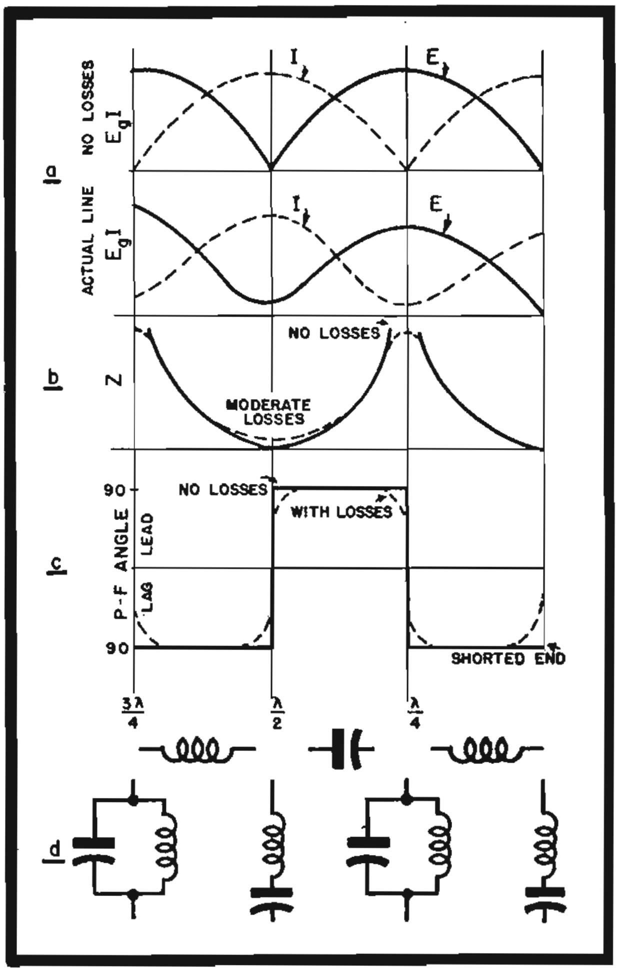
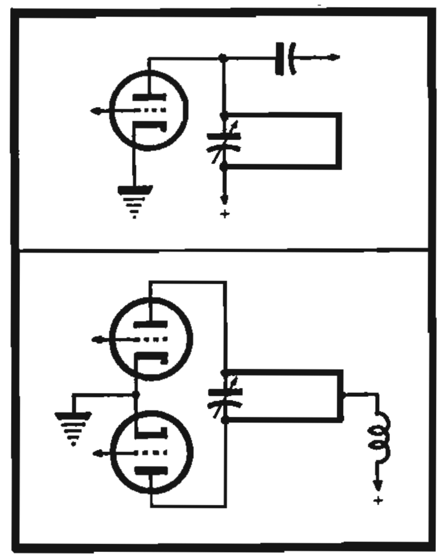


Figure 2
Shorted line characteristics. Resultant current, voltage, impedance and power factor angle variations are presented.

Figure 3
Lines as inductances in two typical circuits.



the current waves, because of the phase reversal, add to give zero current. At other points along the line these waves combine to give different values.

Open Lines

Figure 1*a* shows a plot of the magnitudes of the resultant voltage and current for both a line without losses, and a practical line with small losses. The distance scale is laid off from the receiving or open end in terms of wavelength of the applied signal. It will be observed that the variations are cyclic and that at the point where the current is a maximum, the voltage is a minimum and vice versa. The impedance variations are shown in Figure 1*b*, while the power factor angle is shown in 1*c*. These curves immediately suggest interesting possibilities. From the end of the line to the first quarter-wave point the impedance has a negative angle of 90°, hence the line behaves as a pure capacitance. At the quarter-wave point the impedance reverses sign, going through a very low value of pure resistance. For the next quarter-wave section the angle of the impedance is 90° positive, the line behaving as a pure inductance. The impedance continues to alternate between capacitance and inductance every quarter wavelength. The characteristics at the odd quarter-wave points are those of a series-resonant circuit. At the even quarter-wave points they are those of a parallel resonant circuit; the impedance goes to a very high value while the power factor angle goes through zero. The circuits to which each point or section is equivalent are shown in Figure 1*d*.

Short-Circuited Lines

A somewhat similar situation exists on a short-circuited line, since at the closed end the current will be reflected without change of phase and the voltage with a reversal of phase. The resultant current, voltage, impedance, and power factor angle variations are shown in Figure 2. While these are very similar in appearance to those of Figure 1, there are important differences. The odd quarter-wave points now show the characteristics of parallel resonance and the even quarter-wave points behave like series resonant circuits. Also, the sign of the impedance angle between these points is the reverse of the open line, i.e., the first quarter wavelength now behaves as an inductance and so on.

Much valuable information has been obtained regarding the characteristics of open and short-circuited lines from a study of the voltage and current distribution curves, but to make actual calculations certain equations are necessary. The detailed derivation of most of these may be found in texts on transmission-line theory.

The general transmission-line equations are[1]:

$$I_S = I_R \cosh \gamma l + \frac{E_R}{Z_o} \sinh \gamma l \qquad (1)$$

$$E_s = E_R \cosh \gamma l + I_R Z_o \sinh \gamma l \qquad (2)$$

Here I_s and E_s are the current and voltage at any point a distance l from the receiving end, where the current and voltage are I_R and E_R, γ is the propagation constant, and Z_o is the characteristic impedance of the line. For the two special cases in which we are interested these may be greatly simplified. For the short-circuited line we get

[1]W. L. Everitt, *Communications Engineering*, McGraw-Hill Book Co.

$$I_s = I_R \cosh \gamma l \quad (3)$$

$$E_s = I_R Z_o \sinh \gamma l \quad (4)$$

$$Z_s = E_s/I_s = Z_o \tanh \gamma l \quad (5)$$

For the open line, (*1*) and (*2*) reduce to

$$I_s = \frac{E_R}{Z_o} \sinh \gamma l \quad (6)$$

$$E_s = E_R \cosh \gamma l \quad (7)$$

$$Z_s = \frac{Z_o}{\tanh \gamma l} \quad (8)$$

If we neglect the losses (resistance of the line, shunt leakage conductance, and, for the two-wire line, radiation) equation (*5*) reduces to

$$Z_s = Z_o\, j \tan \beta l \quad (9)$$

where β is the wavelength constant, l is the length of the line and hence βl is the angular length of the line. Similarly (*8*) becomes

$$Z_s = -Z_o\, j \cot \beta l \quad (10)$$

We also have, for the coaxial line[2]:

$$Z_o = 138 \log_{10} b/a, \quad (11)$$

b is the inner radius of the outer conductor and a is the radius of the inner conductor. For a two-conductor parallel line we have

$$Z_o = 276 \log_{10} b/a, \quad (12)$$

b being the spacing, center to center, and a the conductor radius.

These last four equations allow us to calculate the dimensions of lines to give a desired inductive or capacitive reactance. As an example, suppose we want a 200-megacycle tank circuit consisting of a line tuned with a 3-mmfd capacitor. Reference to Figures 1 and 2 or equations (*9*) and (*10*) shows that the shortest line to give inductive reactance will be a short circuited one. Let us assume a parallel line of ½" diameter tubes spaced 1" on centers. From equation (*12*) we find that

$$Z_o = 276 \log_{10}(1/\tfrac{1}{4}) = 166 \text{ ohms}$$

For resonance

$$X_L = X_c = \frac{1}{2\pi(2\times 10^8)(3\times 10^{-12})} = 266$$

This must be the impedance presented by our line. Thus equation (*9*) gives

$$j266 = 166\, j \tan \beta l$$

$$\beta l = 58°$$

Since a wavelength at this frequency is $(3\times 10^8)/(2\times 10^8) = 1.5$ meters, the required length of line is

$$\frac{58}{360} 1.5 = .242 \text{ meter or } 9.5''$$

The application of this line in typical circuits is shown in Figure 3. If the resistance of the line is considered, we get a correction of approximately .5%, so our computations neglecting this factor are acceptable, the slight error being compensated for by adjustment of the tuning capacitor.

A line may also be used as a capacitance, but since capacitance units are more easily built than are inductance types in small sizes, this application is less widely used than the one just described. As a capacitance the line presents an interesting aspect which has application in certain cases; it appears as capacitive reactance to a-c but passes d-c.

As shown by the curves of Figures 1 and 2 a line of the proper length may be used alone as a resonant circuit. When used in this manner the Q becomes important. Thus it is necessary to consider the losses, for, just as in conventional resonant circuits, the losses modify the response at resonance. In spite of these losses, the Q of the resonant line may be made very high, far higher than is possible in a lumped component circuit.

For resonance, the lines must be multiples of quarter wavelengths as pointed out previously. With this condition, equation (*5*) for the short-circuited line and equation (*8*) for the open line both reduce to

$$Z_s = \frac{Z_o}{\tanh \alpha l} = \frac{Z_o}{\alpha l}, \quad (13)$$

where α is the attenuation constant. For a line with no shunt leakage (all practical lines used as resonant circuits will satisfy this to a very high degree of accuracy), α is equal to $R/2Z_o$, R being the resistance per unit length. For the coaxial line, this resistance is given by the relation[3]

$$R = 41.6\sqrt{f}\left(\frac{1}{a}+\frac{1}{b}\right)10^{-9} \text{ ohm/cm}$$

Here f is the frequency, and a and b are the radii in centimeters of the inner and outer conductors. For a parallel two-conductor line where the ratio of the spacing to the radius, (b/a), is large

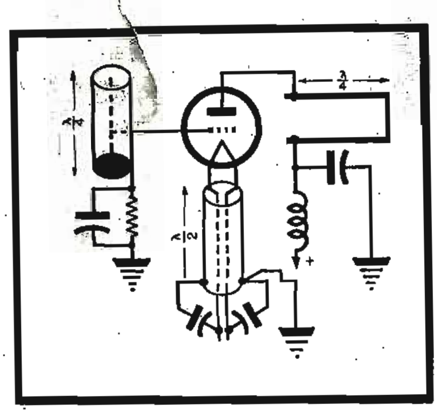


Figure 4
Lines as resonant circuits. Grid is connected to an intermediate point rather than at open end to provide as light a loading as is consistent with reliable oscillations.

$$R = \frac{83.2\sqrt{f}\times 10^{-9}}{a} \text{ ohms/cm},$$

where a is the radius of the conductors in centimeters. If b/a is less than *12*, this gives a value which is low, being about a 1% error for $b/a = 12$ and rising to a 16% error for $b/a = 4$. With the value given above for α, (*13*) becomes

$$Z_s = \frac{8 Z_o^2 f}{R n c}, \quad (14)$$

where n is the number of quarter wavelengths in the line and c is the velocity of light (3×10^{10} cm/sec). The impedance is a function of b/a for both types of line, but is a maximum for the coaxial line when b/a is 9.2 and for the parallel conductor line when b/a is 8. These values are not critical, the value of Z_s changing but little for appreciable changes of the ratio on either side of these

(*Continued on page* 51)

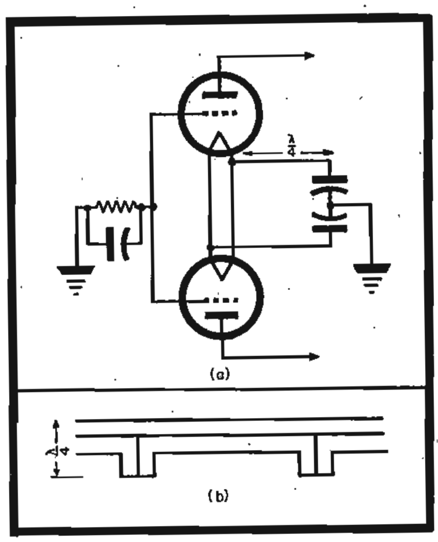


Figure 5
Quarter-wave lines as high impedances. The center conductor is supported by quarter-wave stubs.

[2]Sterba, E. J. and Feldman, C. B., Proc. IRE; July, 1932.

[3]Terman, F. E., Elec. Eng., p. 1046; Vol. 53, 1934.

FCC APPROVED A-M Broadcast Transmitters

Highlights of 100-Watt to 50-KW A-M Transmitters Recently Approved by FCC as Meeting the Standards of Good Engineering Practice.

by RALPH G. PETERS

When the FCC *Standards of Good Engineering Practice Concerning Standard Broadcast Stations* were issued, amendments on approved equipment were included to guide prospective station applicants. During the war it was, of course, impossible to include many of these new-equipment amendments. However, with the conclusion of the war, equipment standards are beginning to be released again. In one of these standard amendments, the FCC has approved a group of a-m transmitters with powers ranging from 100 watts to 50 kw.

Among the transmitters that have received FCC approval are: Collins 100/250 watt (300-G); Gates 1 kw (1-D); and five RCA models, ranging from 250 watts to 50 kw (BTA-250L, BTA-1L, BTA-5F, BTA-10F, BTA-50F, respectively).

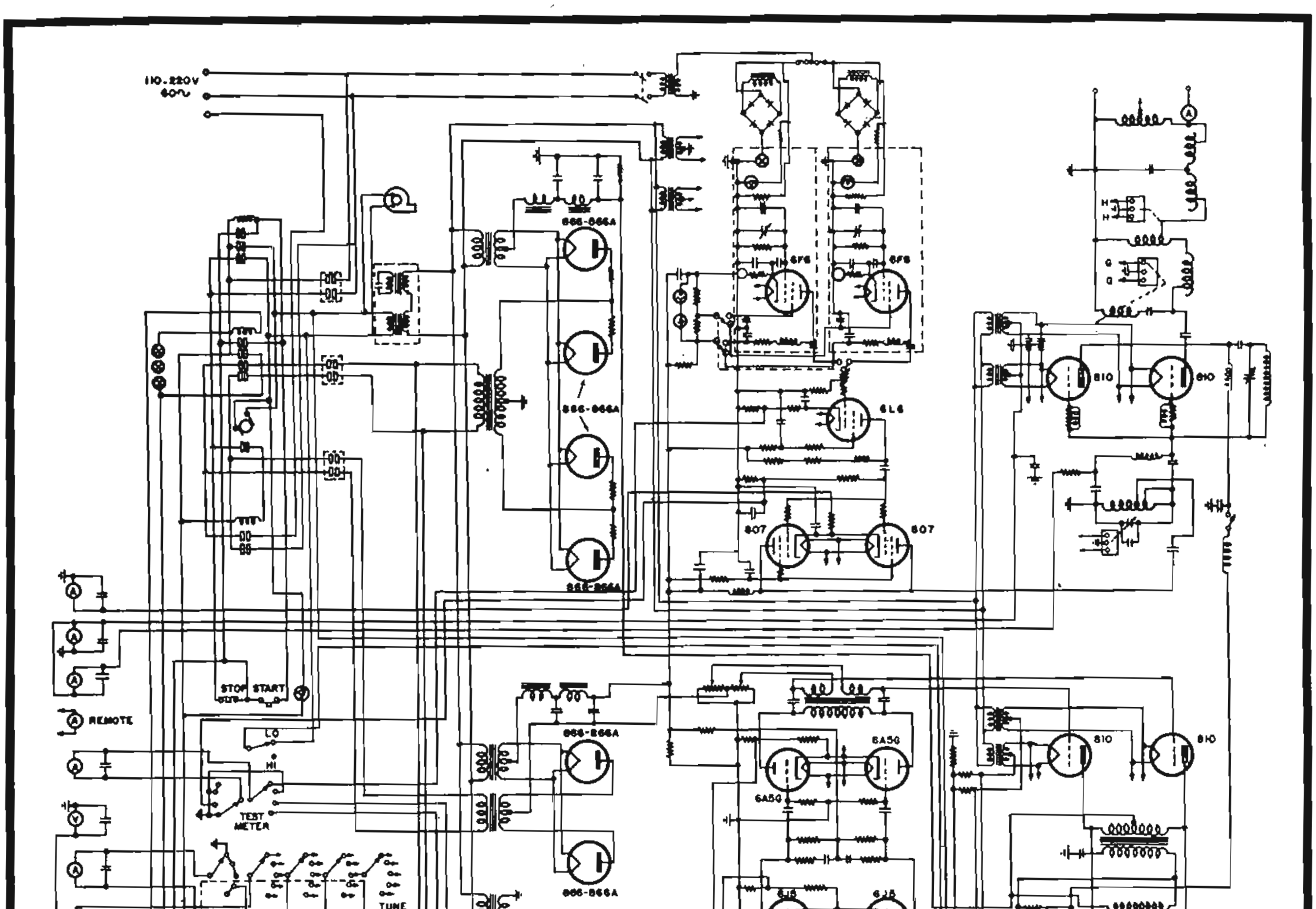
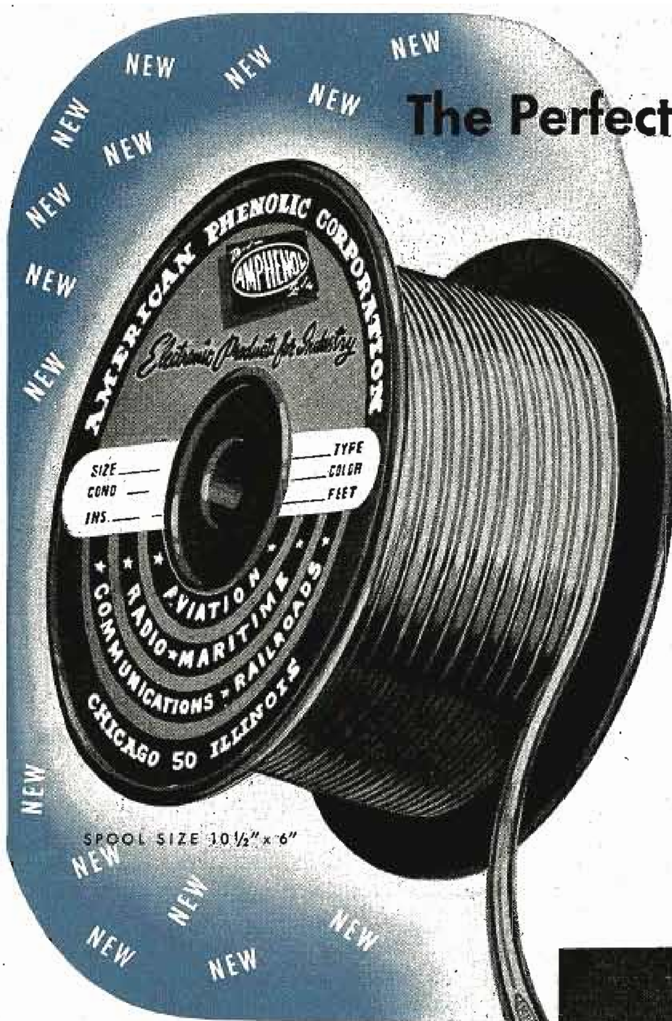


Figure 1
Circuit of the Collins transmitter.

Collins Transmitters

Many interesting features have been included in these FCC-approved mod-

AMPHENOL



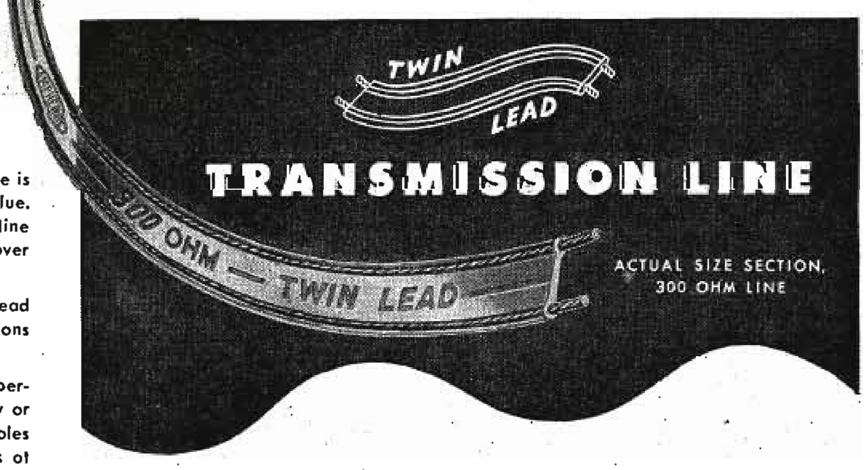
The Perfect Parallel Line Lead-in Wire

Amphenol Twin-Lead is a new type of radio frequency transmission line which combines the low cost of an open line with the excellent dielectric qualities of Polyethylene as a continuous spacer and insulator for the line. It is light and flexible—it can be tacked to a wall and is easy to lead in under a window sash. Its resistance to moisture, cold and heat is far superior to the usual rubber insulated, woven-braid-covered twisted pair used for antennas prior to the war.

Twin-Lead is made in three impedances that serve numerous applications. Selection of type is a simple matter. The *300 ohm* line is the most universal in use, particularly for FM and Television reception. Amateurs are using this line for both antenna and lead-in. The *150 ohm* type is excellent for antennas used mostly for short-wave broadcast reception, and is useful as a link between stages of a transmitter. The *75 ohm* line, originally designed for amateurs who operate in narrow bands of frequency, is also many times better for broadcast reception than the conventional rubber covered or cotton covered wire generally used.

It is to be emphasized that Amphenol Twin-Lead should not be thought of as exclusively for use at ultra-high frequencies. It is THE antenna lead-in for all frequencies.

AMERICAN PHENOLIC CORPORATION
CHICAGO 50, ILLINOIS
In Canada • Amphenol Limited • Toronto



ELECTRICAL DATA

TWIN 300 LEAD — Amphenol "Twin-Lead" Transmission Line is available in 300-ohm impedance value. RMA standardized on 300-ohm lead-in line for Television as the most efficient over broadband operation.

TWIN 150 LEAD — Amphenol also supplies 150-ohm twin-lead to those interested in particular applications and experimental work.

TWIN 75 LEAD — Designed especially for amateurs who operate in very narrow bands of frequency or one particular frequency. Ideal for dipoles with a nominal impedance of 72 ohms at the frequency for which they are cut. This line is also excellent for broadcast reception.

Dielectric constant of Polyethylene—2.29. Capacities (mmf per ft.): "300"—5.8; "150"—10; "75"—19.

Velocity of propagation (approximately): "300"—82%; "150"—77%; "75"—69%.

Power factor of Polyethylene—up to 1000 Mc—.0003 to .00045.

Depend upon AMPHENOL Quality

ATTENUATION—FM AND TELEVISION BAND

Megacycles	300-ohm DB per 100 Ft.	150-ohm DB per 100 Ft.	75-ohm DB per 100 Ft.
25	0.77	0.9	1.7
30	0.88	1.03	2.0
40	1.1	1.3	2.5
60	1.45	1.8	3.4
80	1.8	2.25	4.3
100	2.1	2.7	5.0
200	3.6	4.7	8.3

COAXIAL CABLES AND CONNECTORS • INDUSTRIAL CONNECTORS, FITTINGS AND CONDUIT • ANTENNAS RADIO COMPONENTS • PLASTICS FOR ELECTRONICS

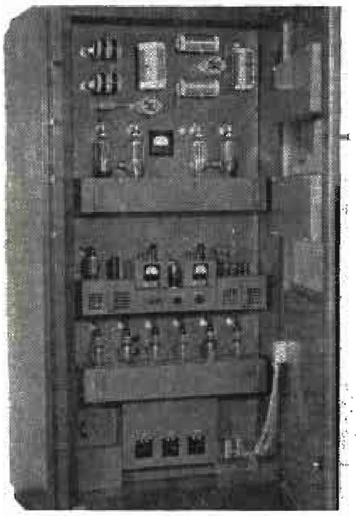


Figure 2
Front view of the Collins 100/250 watt transmitter.

els. The Collins model, for instance, provides for power-output switching from 250 to 100 watts via a switch on the control panel.

This model also features two separate and complete oscillators. Either oscillator may be selected by means of a switch located on the r-f and audio driver unit. High level modulation is used in the final stage.

The audio system uses a feedback circuit, and has a 30- to 10,000-cps frequency response, ± 1 db. The input level for 100% modulation is +10 dbm (1 milliwatt 600-ohm base).

High level class *B* modulation is used. The distortion is less than 3% up to 95% modulation.

RCA Transmitters

The RCA BTA-250L unit uses a class *C* amplifier with two 810s connected in parallel. They are plate modulated by two 828 modulators operating as class *B*.

An average program level of +8 vu is available in the audio system.

The 100% modulation level is +16 dbm. This model also offers a frequency response of 30 to 10,000 within ± 1.5 db.

Figure 4
Frequency characteristics of the Collins transmitters when operating on 250 watts.

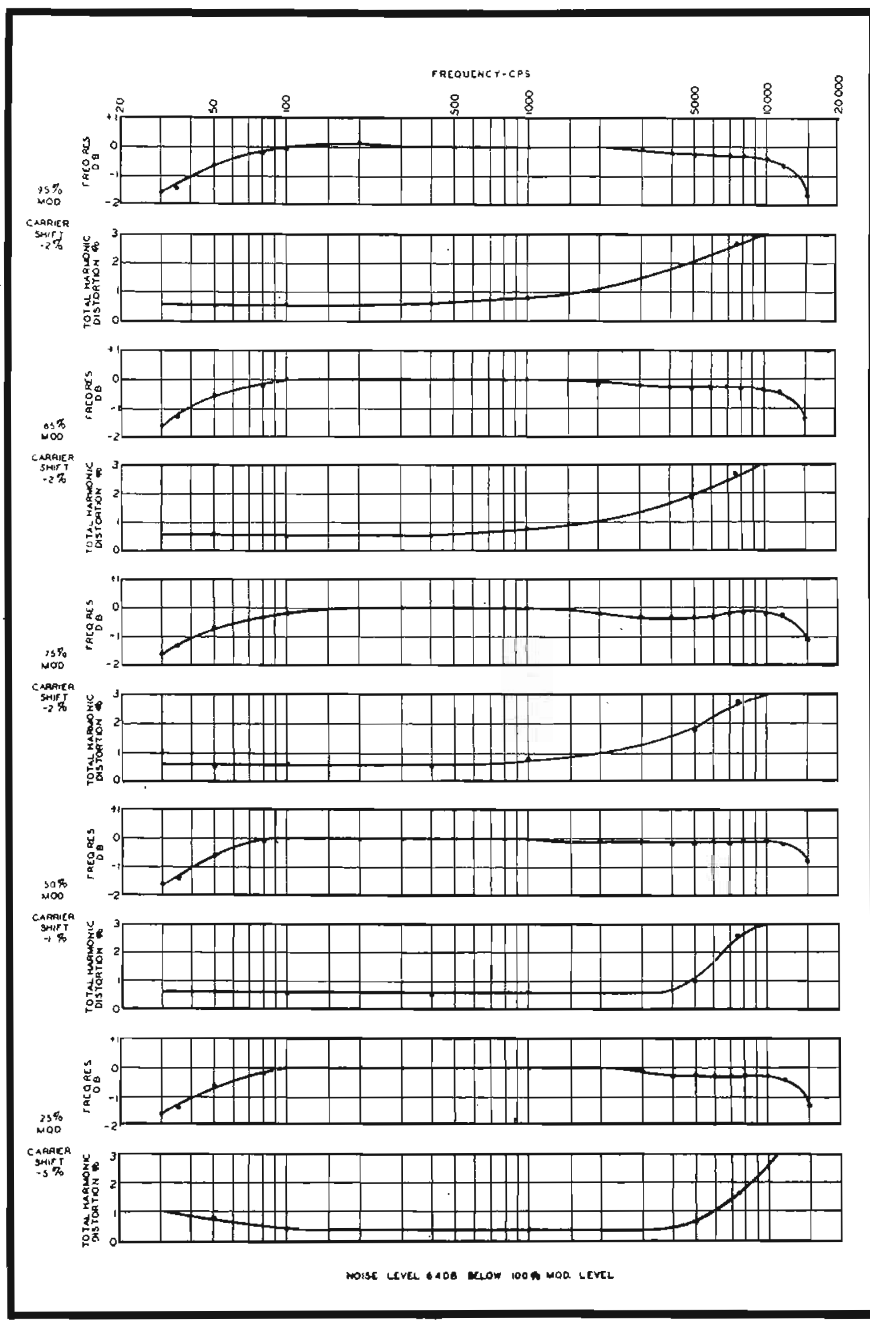


Figure 3
Rear view of the Collins transmitter showing the power supply and filter system.

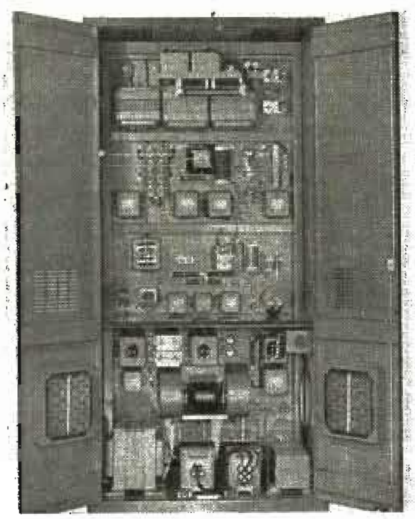
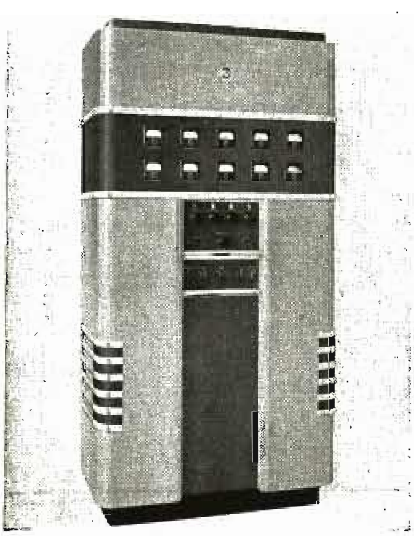
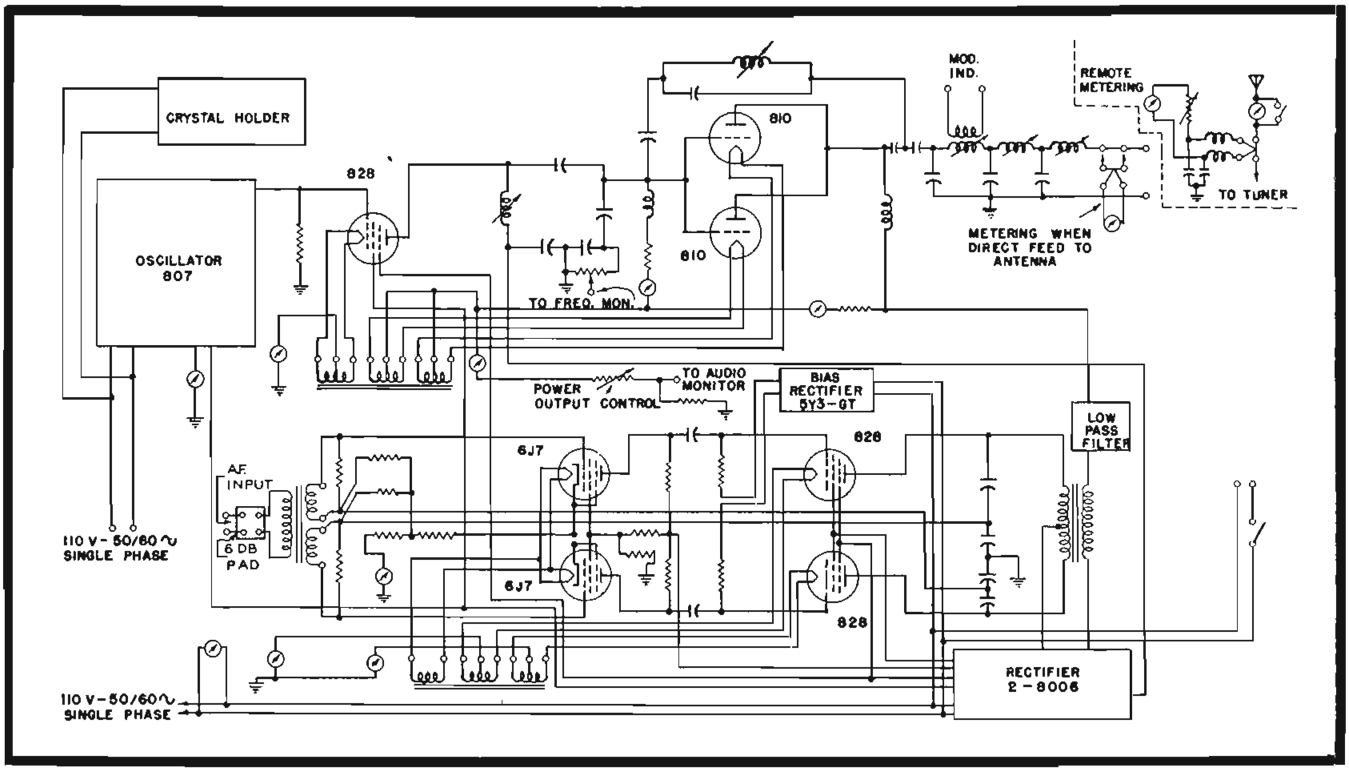


Figure 5
Front view of the RCA 250-w a-m transmitter.





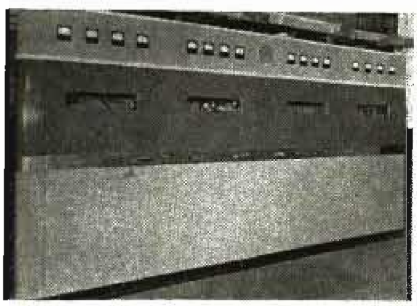


Figure 6
Schematic of the RCA 250-w transmitter.

Figure 7
Front view of the 5- and 10-kw RCA models.

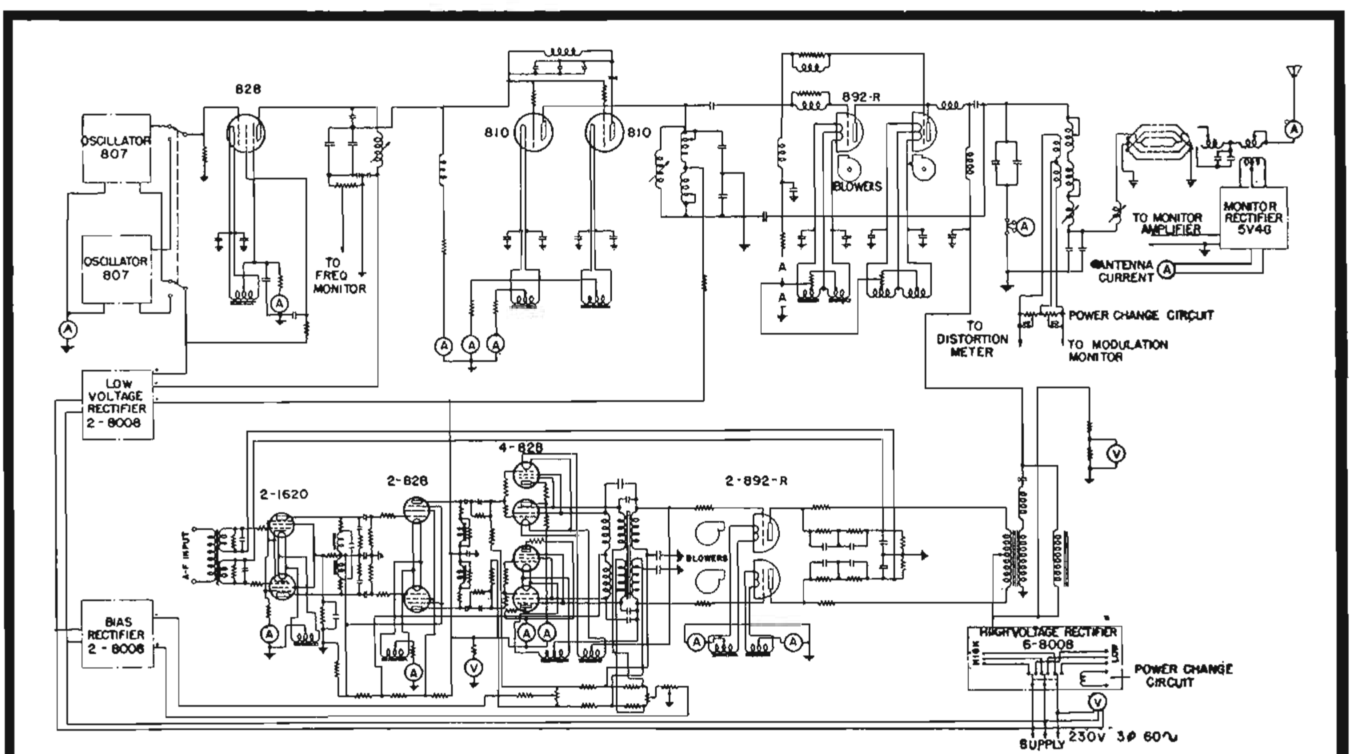
Figure 8
Circuit of the 10-kw RCA a-m transmitter.

The carrier shift of this model at 50 to 75 cycles (0 to 100% modulation) is less than 5%.

The BTA-5F and BTA-10F also have several interesting features. For instance, the output stage of the BTA-5F uses a single 892R operated as class *C* and plate modulated by two 892Rs operating as class *B*.

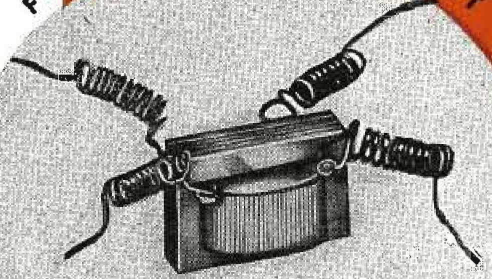
In the BTA-10F, two 892Rs are used in the output stage, and four 828s

(Continued on page 33)



for every transformer application

FOR MINIATURE EQUIPMENT

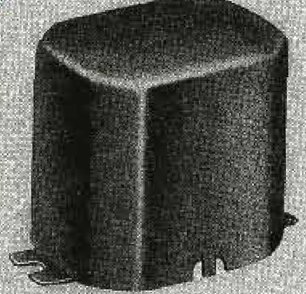


Miniature components to match the new "proximity fuse" miniature tubes. Output and input transformers, and reactors with dimensions 9/16" x 3/4" x 5/8".

FOR THE RESEARCH LABORATORY

Typical of the special units produced by UTC is this high gain, 100 cycle, matching transformer. Primary impedance 500 ohms, secondary impedance 37,500,000 ohms, shielding suitable for—160 DB signal level.

FOR THE RADIO AMATEUR



UTC Special Series components cover the entire range of amateur and low priced PA requirements . . . attractively cased . . . economically priced.

FOR THE BROADCAST STATION

UTC linear standard transformers are the ultimate in high fidelity design . . . frequency response guaranteed ± 1.5 DB 20 to 20,000 cycles . . . Low wave form distortion . . . Extremely low hum pickup.

ARMY E NAVY
ALL PLANTS

United Transformer Corp.

150 VARICK STREET • NEW YORK 13, N. Y.

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

4-COLOR Facsimile Transmission

by E. CHISHOLM THOMSON

London, England

SUCCESSIVE facsimile photo transmissions that permit four-color process reproduction were recently initiated between England and Australia by the Cable and Wireless, Ltd., in London.

The four colors . . . yellow, red, blue and black . . . were represented in four photos, sent out in four separate transmissions.

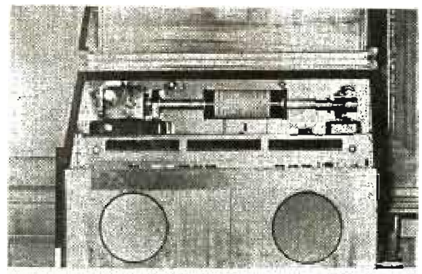
The idea of color transmissions originated last autumn when the "Australian Women's Weekly" proposed that a full-scale colored fashion plate radioed from London would make a good experimental feature. The clothing magazine, "International Textiles," in London, agreed to supply a multicolored fashion plate which had already been published. Cooperation went still farther, in that the London magazine supplied the process-engravers four progressive color proofs in black, yellow, red and blue, with duplicates of all four printed in black.

The four *blacks* were transmitted in succession, suitably labelled with their respective colors, and picked up at the Amalgamated Wireless (Australasia) Melbourne short-wave station. Within a fortnight or so, a complete color picture was sent back to London by air mail. The picture itself was moderately good, though not by any means an exact color facsimile, but this was largely due to the experimental nature of the transmission and the fact that the printers' inks were not accurately matched.

The four separate colors had been superimposed almost to a hair's-breadth, with only a slight staggering which affected the register in some places.

The photo-machine, feeding a transmitter operating on a sub-carrier frequency-modulation system, required between six and ten minutes to transmit a 10″ x 6″ picture.

The colored-print process transmissions introduced an unusual problem. The fashion plate offered was like most other 4-color process pictures, in half-tone. However, the Australian magazine, printed by rotogravure, could not use this halftone. They required a *continuous-tone* picture. These pictures appear on a copper cylinder, and the image is bitten into the copper by acid. In the course of printing, ink is thrown on the cylinder, which is then scraped, leaving only the recessed image for transferring to paper with



Facsimile equipment designed by Cable and Wireless, Ltd., of London, used during transmissions of black and white photos that were employed to make up a 4-color process plate.

an extremely fine *screen* effect, tantamount to continuous tone.

By the half-tone process, a comparatively coarse screen emerges, as the picture is broken up into a mass of dots of varying sizes.

The danger, then, in attempting to print a half-tone picture by the photogravure system was a double-screen effect, with consequent blurring, especially at the edges of the image.

When, however, the half-tone was received in Melbourne, it was found that the dots, combining with the transmitted picture lines, had cancelled out the screen effect, giving a practically continuous tone. Unfortunately, the Australian magazine did not find the prints suitable for their own purposes but they were sent to a local photo-engraver, who made the set of color blocks according to the radioed directions, proofed the complete picture and air-mailed it to London.

Side by side with the original, the picture was astonishingly similar. The color tones were not too accurate but a numbered color code is expected to eliminate that problem.

One of the main flaws was prompted by fading, aggravated by the fact that the colors were transmitted separately. As a result, fading occurred at different places in the picture, giving a blotchy effect to the color. The fading problem may cause more trouble in the development of the system than the actual choice of colors.

One suggestion is to transmit the four prints simultaneously from separate stations, at non-fading periods of the day. Relay nets and frequencies not too susceptible to fading are another suggestion.

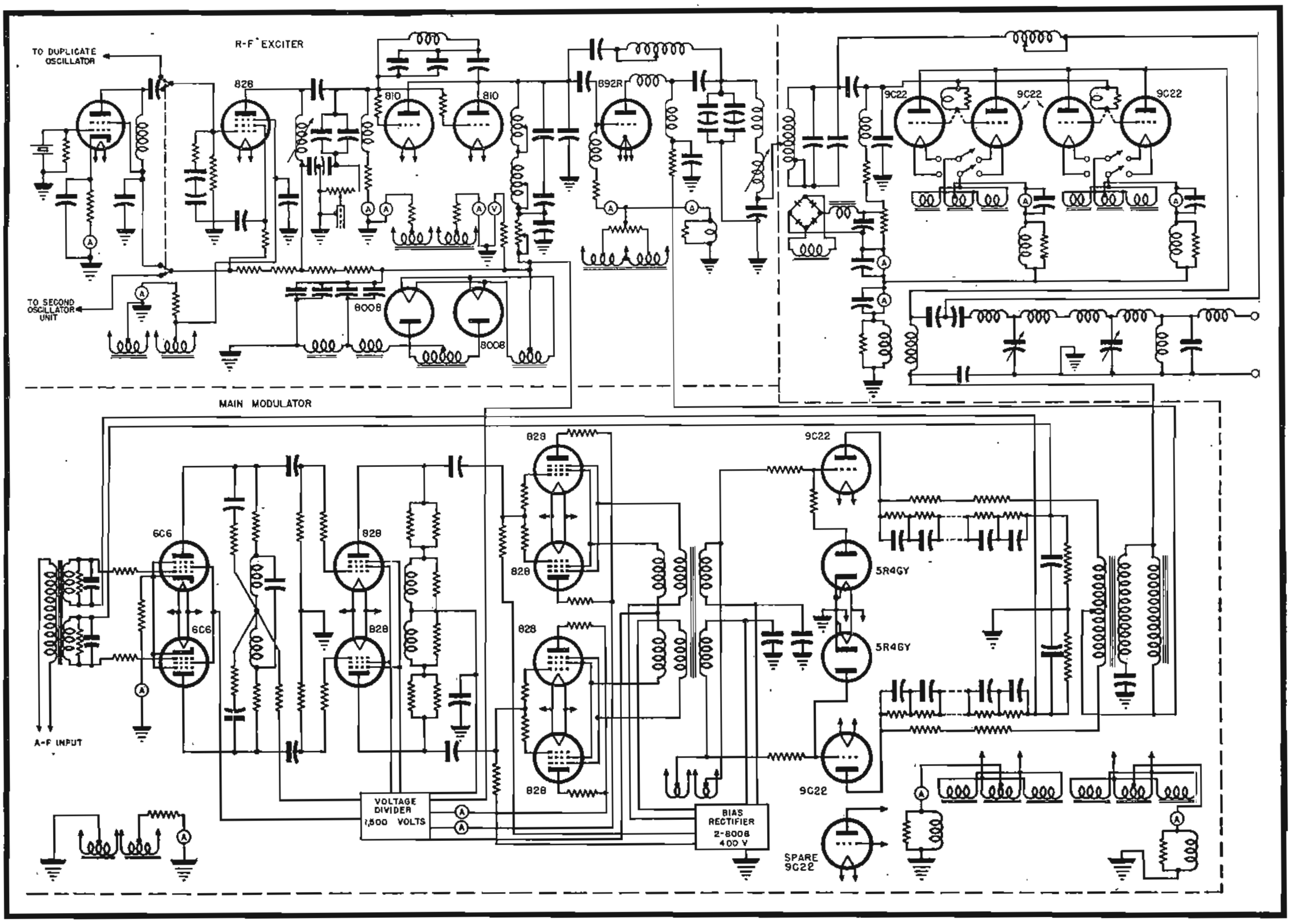


Figure 9
Schematic of the 50-kw RCA broadcast transmitter.

(*Continued from page* 30)
are used in the driver stage of the class *B* modulator.

Power reduction to 1 and 2 kw in the 5- and 10-kw models respectively, is possible by a switching arrangement. Where there are repeated overloads, the power is automatically reduced to

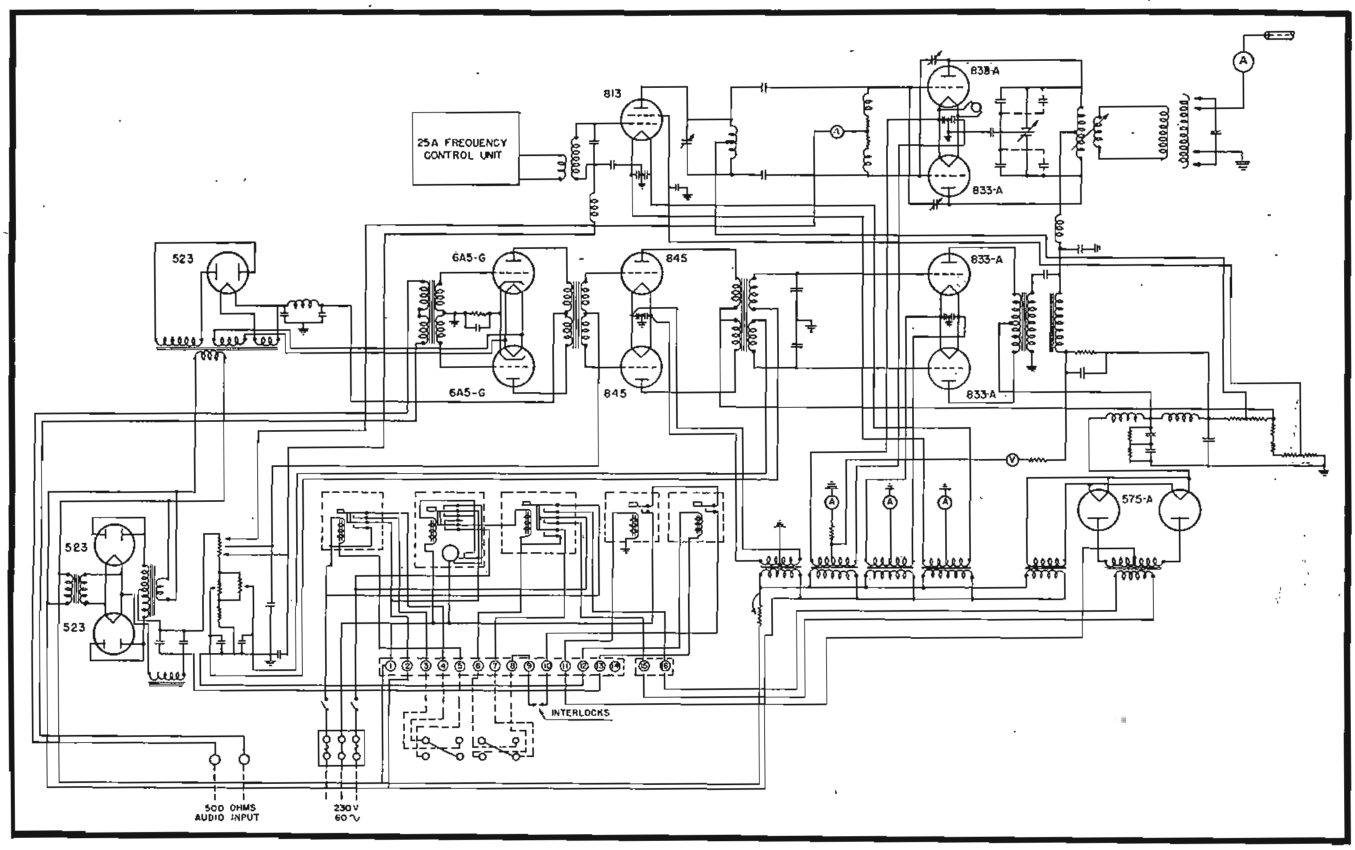


Figure 10
Circuit of the Gates broadcast transmitter.

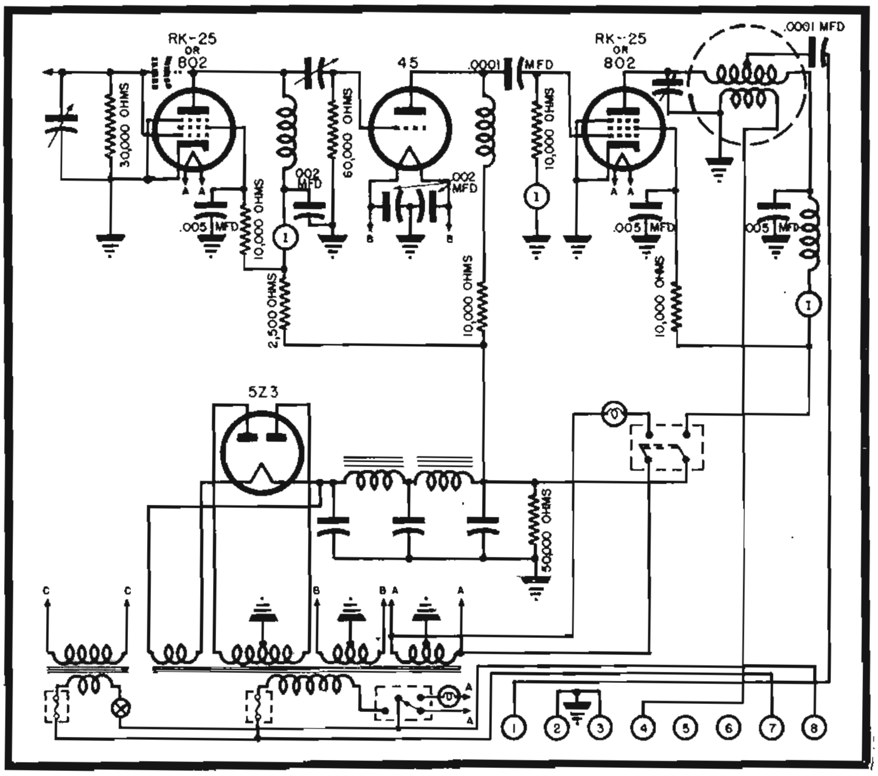


Figure 11
Automatic-frequency control unit used with the Gates 1-kw transmitter.

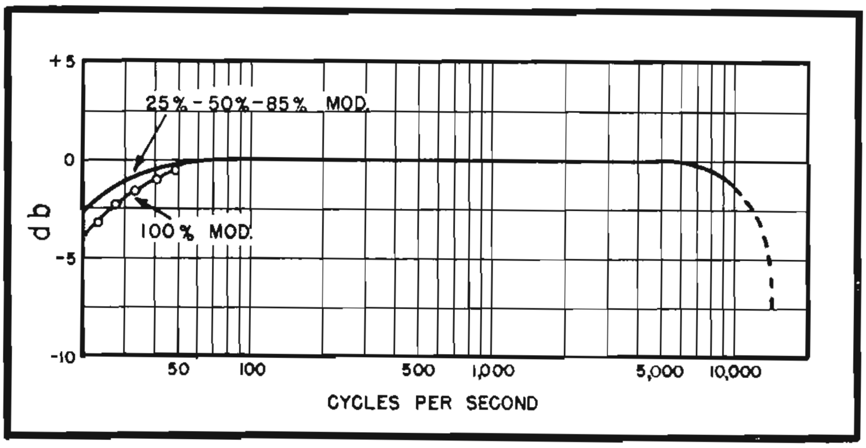
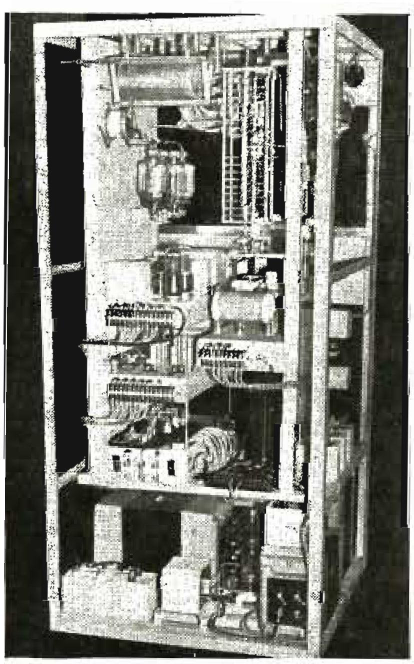


Figure 12
Frequency-response curve of the Gates 1-D transmitter.



the lower level. If an overload occurs in the lower power level, the transmitter is automatically turned off.

The modulator output circuit employs a *splatter filter*, which provides a sharp cut off above 10,000 cycles to eliminate adjacent channel interference.

The average program level for either of these models is +4.5 vu, while the 100% modulation level is +12.5 dbm.

The 50-kw transmitter is an air-cooled model, with a power output stage operated as a class *C* r-f amplifier, amplitude modulated by a class *B* modulator. This modulator is driven by a cathode follower stage to minimize distortion and noise level. Another noise reducing feature is included in the filament system where the power-amplifier tubes have single-phase filaments operated in quarter-phase circuits.

Figure 12b
Rear view of the Gates 1-kw transmitter.

Three tube-type rectifiers are used: A single-phase full-wave unit supplies plate power for the r-f and a-f stages; single-phase full-wave unit supplies bias voltage for the cathode follower and modulator tubes; and a three-phase full-wave high-voltage system provides plate power for a 5-kw r-f driver tube, modulator and the final r-f power amplifiers.

A hum frequency feedback unit is also included, using one 6C6, five Y3GTG, one 6X5GTG, and one 89.

Audio distortion in this model is kept to less than 3% rms, from 50 to 7,500 cps, at 90% modulation. Carrier shift is less than 5% up to 95% modulation.

Gates Transmitter

The Gates 1-kw transmitter provides class *B* modulation, capable of 100% modulation.

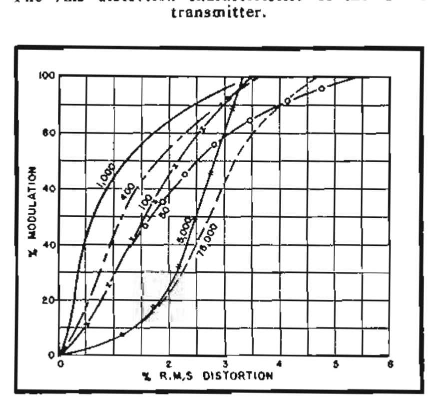
An audio response from 30 to 10,000 cps, within 1.5 db, is provided; the audio input at 100% modulation being approximately +8 vu.

At 25% modulation the carrier shift is zero; at 50% modulation 1%, at 85% modulation 2%, and at 100% modulation, 3%.

A selenium-type bias supply system is employed.

In the oscillator and second intermediate power amplifier, 802s are used. The first intermediate power amplifier uses a 45, while the third intermediate power amplifier uses a 813. There are two 833As in the final power amplifier; two 6A5Gs in the first audio amplifier; two 845s in the second audio amplifier and two 833As in the modulator.

Figure 12a
The rms distortion characteristics of the Gates transmitter.



Answers to your Questions about the SHURE "556" *Super-Cardioid Broadcast Dynamic*

Q. *What is meant by Super-Cardioid?*

Answer: Super-Cardioid is an improvement on the cardioid (heart-shaped) pickup pattern, which makes it even more unidirectional. "Super-Cardioid" reduces pickup of random noises by 73% as compared to 67% for the Cardioid, and yet has a wide pickup angle across the front.

Q. *To accomplish this, is it necessary to have two Microphones in a single case?*

Answer: No. The Shure "556" is designed according to the "Uniphase" principle, a patented Shure development which makes it possible to obtain the "Super-Cardioid" pattern in a single compact, rugged unit.

Q. *Over what range does the Shure "556" give quality reproduction?*

Answer: The Shure "556" provides a high degree of directivity, both horizontally and vertically over a wide frequency range from 40 to 10,000 cycles.

Q. *Does the Shure "556" reduce feedback?*

Answer: Yes! Reflected sounds and "spill-over" from loud speakers entering from the rear are cancelled out within the Microphone.

Q. *Can the Shure "556" be used outdoors?*

Answer: Yes. It is insensitive to wind and will withstand heat and humidity. The low impedance models may be used at practically unlimited distances from the amplifier.

Q. *Can the Shure "556" be used for Studio Broadcasting?*

Answer: More than 750 Radio Broadcast Stations in the United States and Canada use the Shure "556" in their studios. Because it can be placed with its back to the wall without picking up reflected sounds or echoes, it facilitates Microphone placement.

Model 556A for 35-50 Ohm circuits—
LIST PRICE $82

Model 556B for 200-600 Ohm circuits—
LIST PRICE $82

SHURE BROTHERS

Designers and Manufacturers of Microphones and Acoustic Devices

225 West Huron Street, Chicago 10, Illinois

CABLE ADDRESS: SHURE MICRO

SHURE

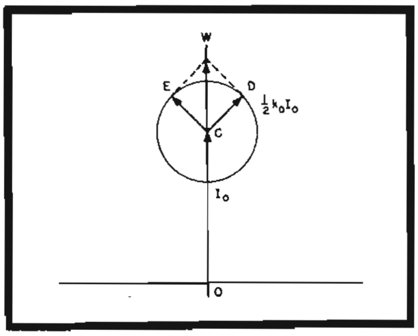


Figure 1

A phasor diagram of an amplitude-modulated wave where OC is the peak amplitude of the carrier; CD and CE, the peak amplitudes of the sidebands; and OW, the resultant wave. In this case the phase of OW remains constant and only its amplitude varies.

PHASE to FREQUENCY

In This, the Fifth Installment in the Series of Papers on the Design and Operation of F-M Transmitters, Is Discussed the Method of Obtaining F-M Through Crystal-Controlled Phase Modulation. An Analysis of the Armstrong and the Phasitron Methods Is Presented.

In the two preceding papers of the series covering *reactance tube modulators* and *direct f-m modulators,* methods of generating f-m signals directly, using a two-terminal reactance network, were discussed. These oscillators cannot be crystal controlled because their very nature demands that the frequency be swung over a considerable portion of its operating frequency. Without crystal control the center frequency of the oscillator will drift beyond the limits set by the FCC. Special control circuits are used to prevent this drift when the above types of f-m generators are used.

Major E. H. Armstrong, however, in his amplitude to phase to frequency modulation provides a circuit which generates an f-m signal from a primary crystal-controlled source. This is referred to as an indirect method of frequency modulation inasmuch as it starts with phase modulation and impresses frequency modulation upon it. The other methods are more of a direct approach since the complete f-m signal is generated and its output is compared to a stable center frequency, the product of which is used to regulate the mid frequency of the f-m generator. Its operation is similar to that of a governor and in many cases must be a small amount off frequency to yield a regulating effect. A few types of bridge circuits are now being introduced to eliminate this deficiency, but it nevertheless still remains a regulation method. Both methods, the direct generation of f-m signals from a crystal oscillator and the regulation of an f-m generator by a crystal oscillator, have their advantages and their disadvantages and the application will determine what method should be used.

The resemblance between the final equations for phase modulation and the final equations for frequency modulation was discussed in the first paper of this series covering *fundamental relationships of f-m systems,* which appeared in the January 1946 issue. The current i in an f-m modulated wave is given by

$$i = I \sin(\omega t + m_f \sin \Omega t) \qquad (1)$$

where: I is the maximum amplitude, t is time chosen so that there is no inherent phase angle at t equal to zero, ω is $2\pi f_o$ where f_o is the center frequency of the f-m signal, Ω is $2\pi F$ where F is the modulating frequency, and m_f is the frequency modulation factor. In phase modulation the current is expressed by an equation which is exactly similar to (*1*) except that m_p, the phase-modulation factor is used, instead of m_f. It is the comparison of these two factors which leads to the use of phase modulation to generate frequency modulation.

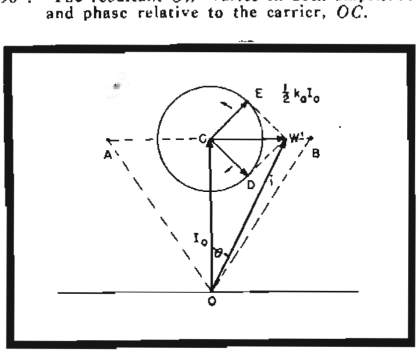


Figure 2

A phasor diagram of an amplitude-modulated wave, wherein the sidebands have been shifted 90°. The resultant OW varies in both amplitude and phase relative to the carrier, OC.

The Modulation Factors

The final result, which is desired, is to have the frequency vary in an f-m wave in a manner directly proportional to the modulating voltage. Calling this proportionality constant, k_f, the expression for m_f is

$$m_f = \frac{k_f f_o}{F} \qquad (2)$$

Substituting (*2*) into (*1*), the instantaneous phase angle, ϕ_f, of the current, i, in an f-m modulated wave becomes

$$\phi_f = \omega t + \frac{k_f f_o}{F} \sin \Omega t \qquad (3)$$

In a phase-modulated wave the instantaneous phase angle must vary in a manner proportional to the modulating voltage. Calling the proportionality constant in this case, k_p, the instantaneous phase angle, ϕ_p, is defined by

$$\phi_p = \omega t + k_p \Phi_p \sin \omega t \qquad (4)$$

where Φ_p is the peak phase variation. Notice the resemblance now between equation (*3*) and (*4*). Normally in straight phase modulation the modulation factor, k_p, is a constant. Suppose now that instead of being a constant it is made inversely proportional to the modulating frequency, F, by

$$k_p = \frac{K}{F} \qquad (5)$$

where K is a constant that determines the maximum value of k_p. Replacing k_p in (*4*) by its new equivalent value as given in (*5*)

$$\phi_p = \omega t + \frac{K \Phi_p}{F} \sin \omega t \qquad (6)$$

Comparing (*6*) and (*3*) it can be seen that if $k_f f_o$, both of which are constants, is made equal to $K\Phi_p$, both of which are also constants, the instantaneous phase, obtained in the method of phase modulation as given in (*6*), will be exactly equal to the instantaneous phase necessary for frequency modulation, ϕ_f, as given in (*3*). What this means is that a frequency-modulated wave is obtained at the output of a phase modulator if the amount of phase modulation resulting at any modulating frequency is inversely

MODULATION

by N. MARCHAND*

Consulting Engineer
Lowenherz Development Company

proportional to the modulating frequency itself.

The Armstrong Phase Modulator

The problem was thus reduced to one of obtaining a crystal-generated phase-modulated wave. This was solved by Major Armstrong, who converted a crystal-controlled amplitude-modulated wave into a phase-modulated wave and thus obtained a crystal-controlled phase-modulated wave. By making the amount of phase modulation obtained inversely proportional to the modulating frequency the output was actually a frequency-modulated wave.

The equation for an amplitude modulated wave is:

$$i = I_o\,(1 + k_a \sin \Omega t) \sin \omega t \qquad (7)$$

where I_o is the peak amplitude of the carrier and k_a is the modulation constant. The other symbols have the same meaning as in the other equations. This equation can be expanded into the sum of a carrier and two sidebands:

$$i = I_o \sin \omega t + \tfrac{1}{2} k_a I_o \cos(\omega - \Omega)t - \tfrac{1}{2} k_a I_o \cos(\omega + \Omega)t \qquad (8)$$

In Figure 1 is shown a phasor diagram of equation *(8)*: *OC* is equal to the peak carrier amplitude, I_o; *CD* and *CE* are the two sideband amplitudes which are equal to $\frac{1}{2} k_a I_o$; and *OW* is the resultant amplitude modulated wave which varies in amplitude with the modulating voltage. It will be noticed that *OW* only varies in amplitude but its phase remains constant. Let us now consider the case where the two sidebands are shifted in phase by an angle equal to 90°, on the phasor diagram. This is illustrated in Figure 2, where an amplitude modulated wave with its side bands, *CD* and *CE*, have been retarded 90° in phase. This phasor diagram shows that the resultant of the side bands,

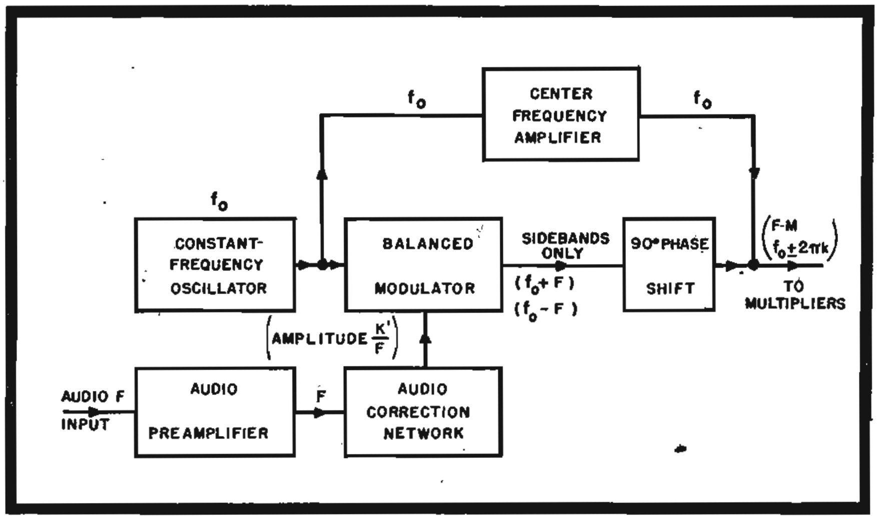


Figure 3

Block diagram of the Armstrong modulator with the input and output frequencies of several stages shown. *F* is the audio frequency; f_o, the fundamental carrier frequency; and $2\pi K$, the resultant deviation.

CW' in the diagram, is now at right angles to the carrier, *OC*. The resultant current *i* will now be represented by the phasor *OW'*. This current will vary in both amplitude and phase in relation to the carrier, *OC*. The angle between the resultant *OW'* and the carrier is called φ. This means that the output can be represented by a phasor which whips back and forth between the limits of *OA* and *OB* where *CA* is equal to *CB*, which is equal to $k_a I_o$. However from trigonometry the current *i* is

$$i = \sqrt{\overline{OC}^2 + \overline{CW'}^2}\,\sin\left[\omega t \pm \tan^{-1}\left(\frac{CW'}{OC}\right)\right] \qquad (9)$$

The magnitude of *OC* is I_o, and the magnitude of *CW'* from *(7)* is equal to the product of $k_a I_o$ and the sine of the angle, Ωt. Assuming that the amplitude variation in the output wave will be removed by some sort of limiter circuit we need only concern ourselves with the instantaneous phase angle, φ. Making the substitutions for *OC* and *CW'* in *(9)* the phase angle is

$$\varphi = \omega t \pm \tan^{-1}[k_a \sin \Omega t] \qquad (10)$$

To produce frequency modulation, k_a is made equal to *K* over *F*. Replacing k_a by this value provides as the output of the modulator, the phase angle

$$\varphi = \omega t \pm \tan^{-1}\left[\frac{K}{F}\sin \Omega t\right] \qquad (11)$$

Comparing equations *(11)* with *(3)* it can be seen that if *K* over *F* is made small enough, so that the arc tangent of the angle can be taken as equal to the angle itself, then the result would be a perfect f-m modulated wave. The actual distortion introduced can be obtained by differentiating *(11)* and obtaining the instantaneous frequency variation. The frequency should be proportional to the modulating voltage in the standard modulation manner. The harmonics that are introduced by the tangent term will make up the distortion. In this manner the maximum phase swing for any specified signal distortion may be obtained.

Calling *f*, the instantaneous frequency,

$$f = \frac{d\varphi}{dt} = \omega \pm \frac{2\pi k \cos \Omega t}{1 + \left(\frac{K}{F}\sin \Omega t\right)^2} \qquad (12)$$

Thus the distortion is introduced by the factor

$$\left(\frac{K}{F}\sin \Omega t\right)^2.$$

If this factor is negligible with respect to 1 the frequency *f* will faithfully follow the modulating voltage. If not it is necessary to run a Fourier analysis of the second term on the right hand side of equation *(12)*. This yields only odd harmonics where the amplitide of the *n*th harmonic, A_n, is given by

$$A_n = 2\pi k \left(\frac{2}{\left(\frac{K}{F}\right)^{n+1}}\left(\sqrt{1+\left(\frac{K}{F}\right)^2}-1\right)^n\right) \qquad (13)$$

This means that the amplitude of the fundamental is obtained by substituting *n* equal to 1 in *(13)*, the amplitude of the third harmonic by substituting n equal to 3 in *(13)* and so forth. Actually the magnitudes of

*Instructor in Graduate Electrical Engineering courses, Columbia University.

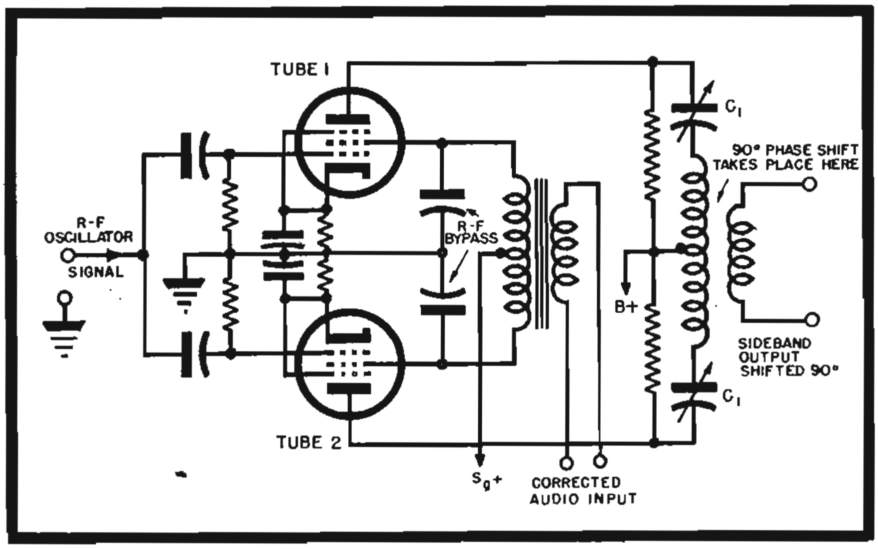


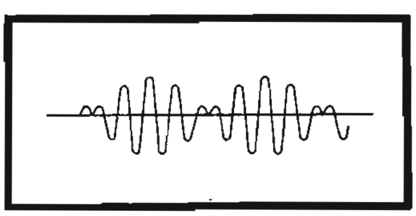
Figure 5
Circuits of a balanced modulator where tubes *1* and 2 are excited by the r-f oscillator in parallel, but are modulated by the corrected audio input in pushpull.

the harmonics drop very rapidly with increase in order of the harmonic so that the only really important one is the third. Suppose now that it is desired to obtain the maximum value of K for a 30 to 15,000-cycle band width, that can be used in the above system without the third harmonic exceeding 5% of the fundamental. Dividing A_3 by A_1 and equating it to .05

$$.05 = \frac{(\sqrt{1 + (K/F)^2} - 1)^2}{(K/F)^2} \qquad (14)$$

Solving for K/F, we find the result to be 0.47. The minimum value of K will be obtained when F is a minimum, which in this case is 30 cycles. At 30 cycles K would be 14.1. Examining *(11)*, the maximum value of the term within the brackets will be equal to K/F inasmuch as the maximum value of the sine term is *one*. This means that the maximum variation in ϕ will be the arc tangent of K/F which in this case is 0.47. The maximum variation in ϕ or $\Delta\phi$, as it is called, will then be plus and minus 25.2°. This, of course, limits the amount of phase modulation that can be put on the wave. From *(12)* the maximum frequency deviation will be K as the sine term will be zero

Figure 6
Resultant wave shape at the output of the balanced modulator. It will be noted that a reversal in phase takes place every time the wave passes through zero amplitude.



when the cosine term is *one*. This means that the maximum frequency deviation in the above case will be 14.1 cycles. This is not very much but it may be multiplied up to any frequency deviation without the introduction of any distortion. Thus if a frequency deviation of 75 kc is desired then it will be necessary to employ multipliers with a multiplication of approximately 5,300.

The Correction Network

In Figure 3 is shown a block diagram of the Armstrong modulator embodying the foregoing principles. The audio input is taken in through some type of preamplifier, as noted. It is then passed through a corrector network which has an output characteristic that is proportional to the frequency of the audio signal. This means that a complex wave form will be distorted in the following manner: The ratio of the second harmonic amplitude to the fundamental amplitude will be reduced to one-half; the ratio of the third harmonic amplitude to the fundamental amplitude will be reduced to one-third; and so forth. A simple circuit that will accomplish the correction is shown in Figure 4. It consists of a resistor, R, in series with the input and a capacitance C in parallel with the output. Assuming a constant voltage, E, at the input and a high enough impedance at the output, so that it is very much greater than the impedance of the C at the frequency F which is employed, the current, I, through the capacitor is

$$I = \frac{E}{R - j\dfrac{1}{2\pi FC}} \qquad (15)$$

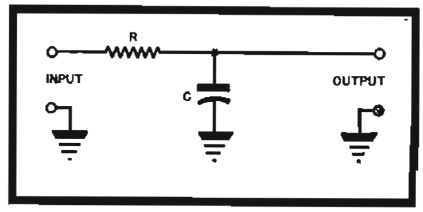


Figure 4
A simple audio-correction network consisting of a series resistor, R, and a parallel capacitor, C. $2\pi FCR$ is made large in comparison to 1, at least greater than 5.

The voltage across the output will be equal to this current times the reactance of the capacitor at the frequency, F. Calling this voltage, E_o, it will be given by

$$E_o = \frac{E}{j2\pi FCR + 1} \qquad (16)$$

Now if $2\pi FRC$ is very much larger than 1 for all values of F involved, the 1 may be neglected. The value of $2\pi FCR$ will be a minimum at the minimum value of F. It should be made equal to at least *5*, larger if possible, at the minimum frequency of the audio band. Neglecting the quantity 1, the final equation for E_o is

$$E_o = -j\frac{E}{2\pi FCR} = -j\frac{E}{K_1 F} \qquad (17)$$

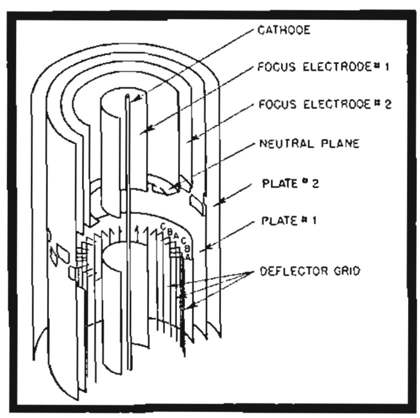
showing that the amplitude of the output will be inversely proportional to the frequency of the input voltage. Of course there will be a loss through the network but since all of this takes place at very low-power levels the loss in power is negligible.

The Balanced Modulator

Returning now to Figure 3, we find that the output of the corrected audio signal is fed into a balanced modulator. The purpose of the balanced

(*Continued on page* 56)

Figure 7
Schematic of the phasitron, showing internal tube construction. Note the staggered holes in the circumference of plate *1*.

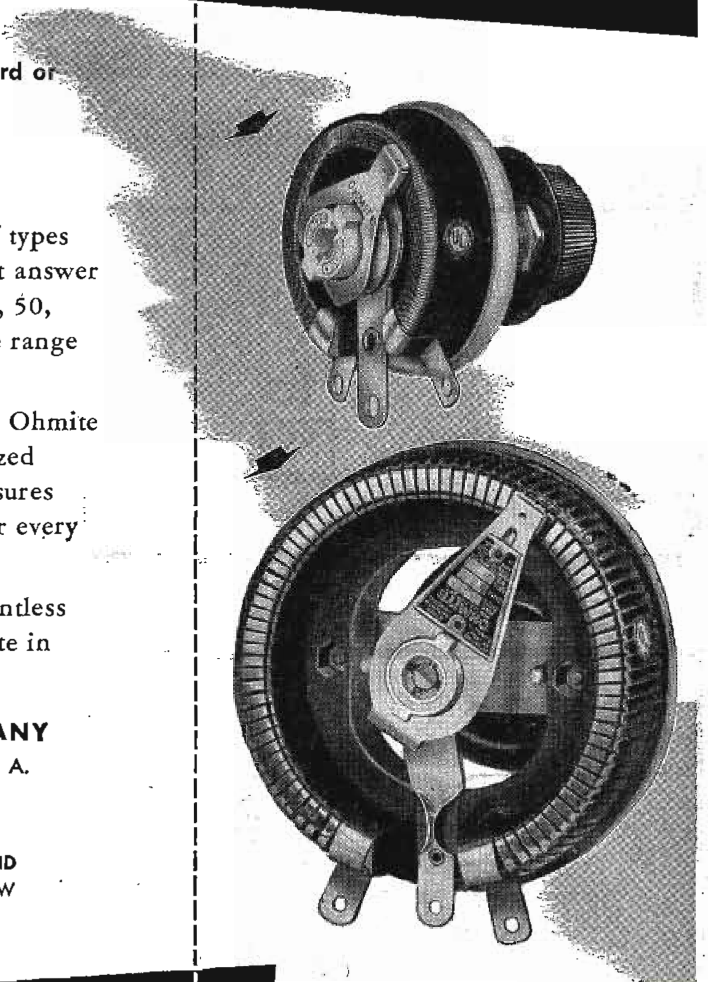


OHMITE

OFFERS THE WIDEST, MOST COMPLETE RANGE OF TYPES AND SIZES IN

CLOSE CONTROL Rheostats

10 Wattage Sizes from 25 to 1000 watts, from 1-9/16″ to 12″ Diameter, with Standard or Special Features, with Uniform or Tapered Windings, in Stock or Special Resistances, in Single, Tandem or Concentric Units.



Only Ohmite provides such a wide range of types and sizes . . . to give you a quick and correct answer to your Rheostat needs. Stock models in 25, 50, 100, 150, 300, and 500 watt sizes in a wide range of resistance values.

All models have the time-proved features of Ohmite design—the pioneer design that revolutionized rheostat construction. Every Ohmite unit assures permanently smooth close control . . . under every operating condition.

Get the benefit of Ohmite experience in countless applications. Let Ohmite engineers cooperate in solving your rheostat control problems.

OHMITE MANUFACTURING COMPANY
4869 FLOURNOY STREET, CHICAGO 44, U. S. A.

★ ★ ★

VISIT BOOTH NO. 72 AT THE RADIO PARTS AND ELECTRONIC EQUIPMENT CONFERENCE AND SHOW
HOTEL STEVENS, CHICAGO, MAY 13-16

Be Right with **OHMITE**

RHEOSTATS • RESISTORS • TAP SWITCHES

Send for Catalog and Engineering Manual No. 40

Write on company letterhead for this valuable helpful guide in the selection and application of rheostats, resistors, tap switches, chokes and attenuators.

Solving 4-TERMINAL NETWORK

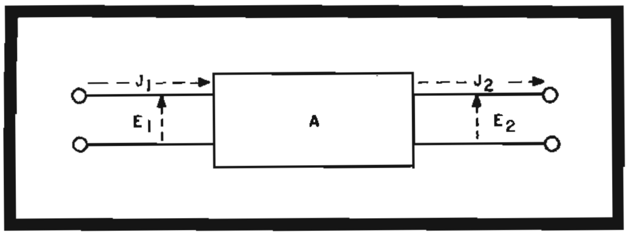


Figure 7
Voltages and currents in a *four terminal network*.

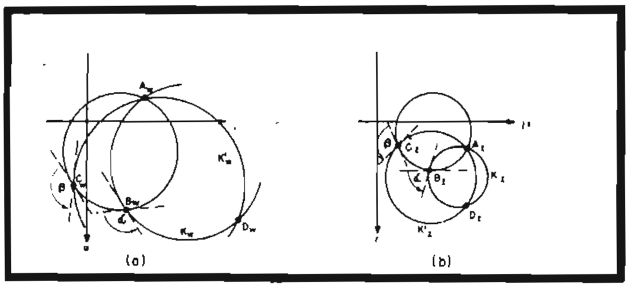


Figure 8
The transformation of the general *four terminal network*, defined by the transformation of three points *A*, *B*, *C*. Additional points can be transformed by the use of auxiliary circles, such as *K* and *K'* for point *D*. [(a) = *w* plane; (b) = *z* plane.]

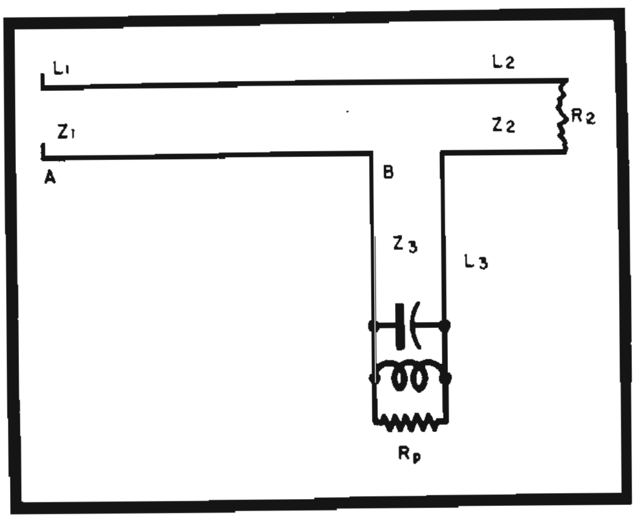


Figure 9
Input arrangement of a network, with three lines, L_1, L_2, and L_3, in series.

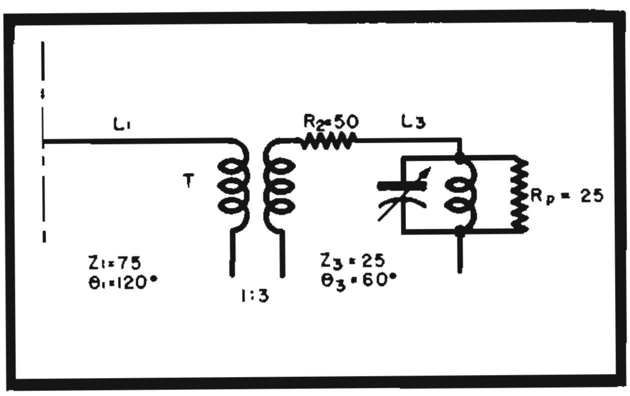


Figure 10
Equivalent for the arrangement of Figure 9. The matched line, L_2, is replaced by a resistance, R_2, and the change in characteristic impedance is indicated by a lossless transformer, *T*.

IN the preceding discussion,[1] we pointed out that we can use an inversion diagram and a Smith diagram to follow up networks containing parallel or series arrangements of lumped constants or lines if we leave the frequency constant and change only the output (load) impedance.

It is also possible to obtain the foregoing result by applying the following procedure:

At A, in Figure 7, we have a quadripole, a network of any kind, having two output terminals and two input terminals, the only restriction being that the network does not contain any non-linear devices. For any quadripole we can write

$$\left.\begin{aligned} E_1 &= a_{11} E_2 + a_{12} J_2 \\ J_1 &= a_{21} E_2 + a_{22} J_2 \end{aligned}\right\} \qquad (10)$$

where: E_1 = input voltage
J_1 = input current
E_2 = output voltage
J_2 = output current
a_{mn} = complex quantities, dependent only upon frequency, or constants, if the frequency is constant.

From the theory of quadripoles, always,

$$a_{11} a_{22} - a_{12} a_{21} = 1$$

Therefore, *(10)* contains only three unknown constants. By division,

$$\frac{E_1}{J_1} = w \quad \text{and} \quad \frac{E_2}{J_2} = z \; : \; w = \frac{a_{11} z + a_{12}}{a_{21} z + a_{22}}$$

which is identical with (1). Therefore, *any quadripole transforms its output impedance according to a linear rational transformation.*

To determine the three unknown constants we have to make three impedance measurements. On the other hand it will not be necessary to draw, in the graphical solution, all circles as they appear when we go step by step through our system of lines and lumped constants. It is sufficient to find the input impedance for only three load impedances.[6] From the three (or two) pairs

[6]In the case of lossless quadripoles, this reduces to either two complex impedances or three reactances.

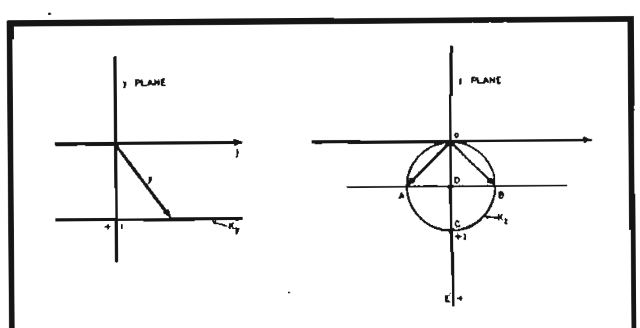


Figure 11
Inversion of the admittance of a parallel-tuned resonant circuit, which furnishes its impedance as a circle, K_z.

[1]Part 1 of this paper appeared in the March issue of COMMUNICATIONS.

PROBLEMS Graphically

[*Part II*]

by RICHARD BAUM

Research Engineer
Raytheon Manufacturing Company

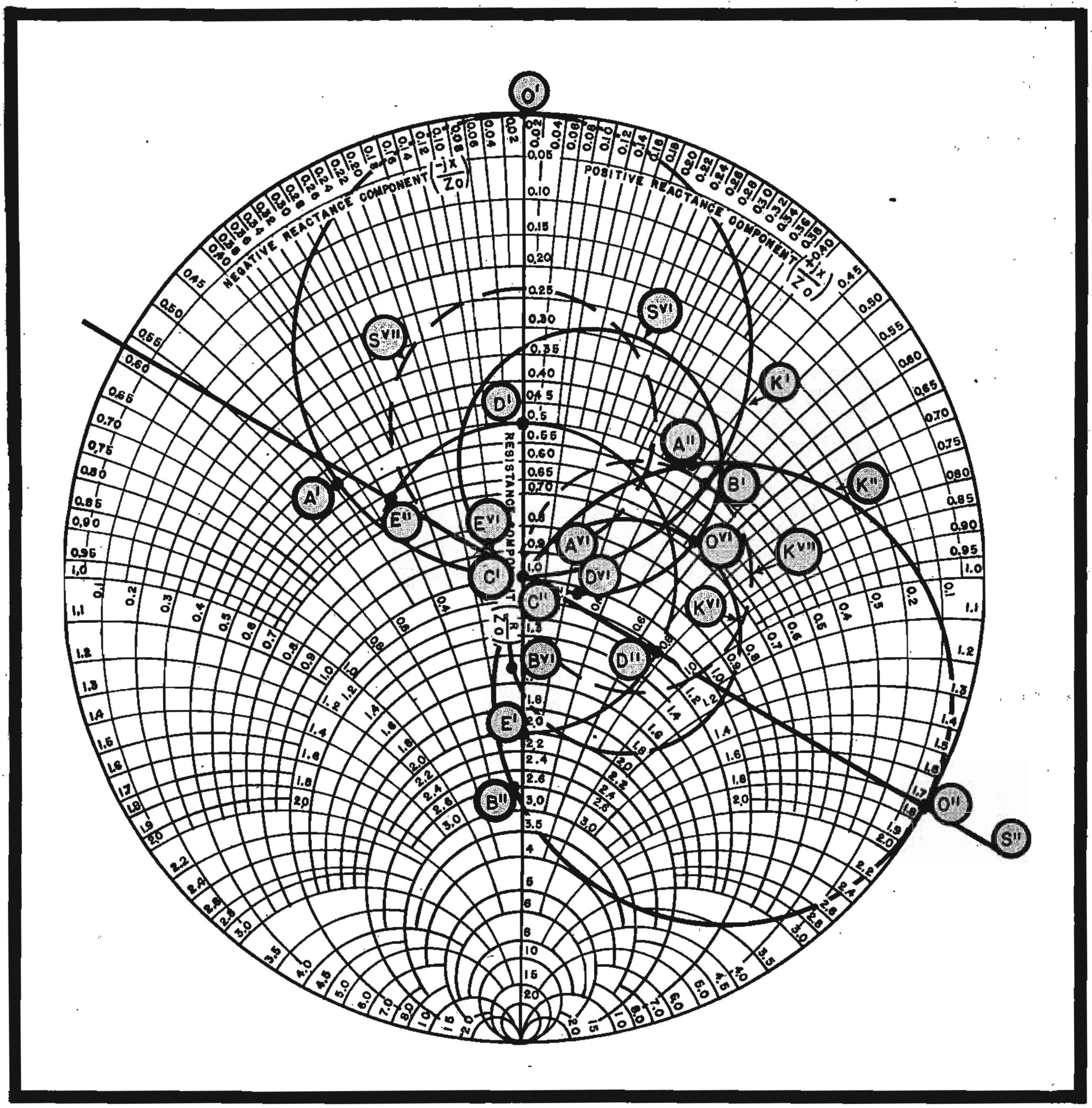
Conclusion of Discussion of Graphical Solution of Impedance Problems Involving Four-Terminal Networks of Lumped or Distributed-Constant Type. Offered in This Installment Are Examples of Application and Use of Smith and Inversion Charts.

of corresponding input and output impedances, we can find the input impedance, for any other output impedance and vice versa.

Transformation of the General Four Terminal Network

Let us assume that we have found that the three-load impedances A_z, B_z, C_z

Figure 12
Solution of an example in the *w* plane with the Smith chart.



COMMUNICATIONS will cost you only $1.00 for the next 12 issues

To the Publisher of
COMMUNICATIONS
52 Vanderbilt Ave., New York 17, N. Y.

Please enter annual subscriptions (12 issues) for each of the undersigned for which payment is enclosed at the rate of $1.00 each. (This rate applies only on 4 or more subscriptions when classifications are given.)

Name ....
Address ....
City-State ....
Occupation ....
Employed by ....
Nature of Business ....
(State If Manufacturer, Broadcast Station, etc.)
Product ....

Name ....
Address ....
City-State ....
Occupation ....
Employed by ....
Nature of Business ....
(State If Manufacturer, Broadcast Station, etc.)
Product ....

Name ....
Address ....
City-State ....
Occupation ....
Employed by ....
Nature of Business ....
(State If Manufacturer, Broadcast Station, etc.)
Product ....

Name ....
Address ....
City-State ....
Occupation ....
Employed by ....
Nature of Business ....
(State If Manufacturer, Broadcast Station, etc.)
Product ....

● A subscription to COMMUNICATIONS will provide timely and authoritative articles of decided importance to every engineer and executive in radio, broadcasting, television, facsimile, sound recording and projection, aeronautical, police, railroad, marine and emergency communications.

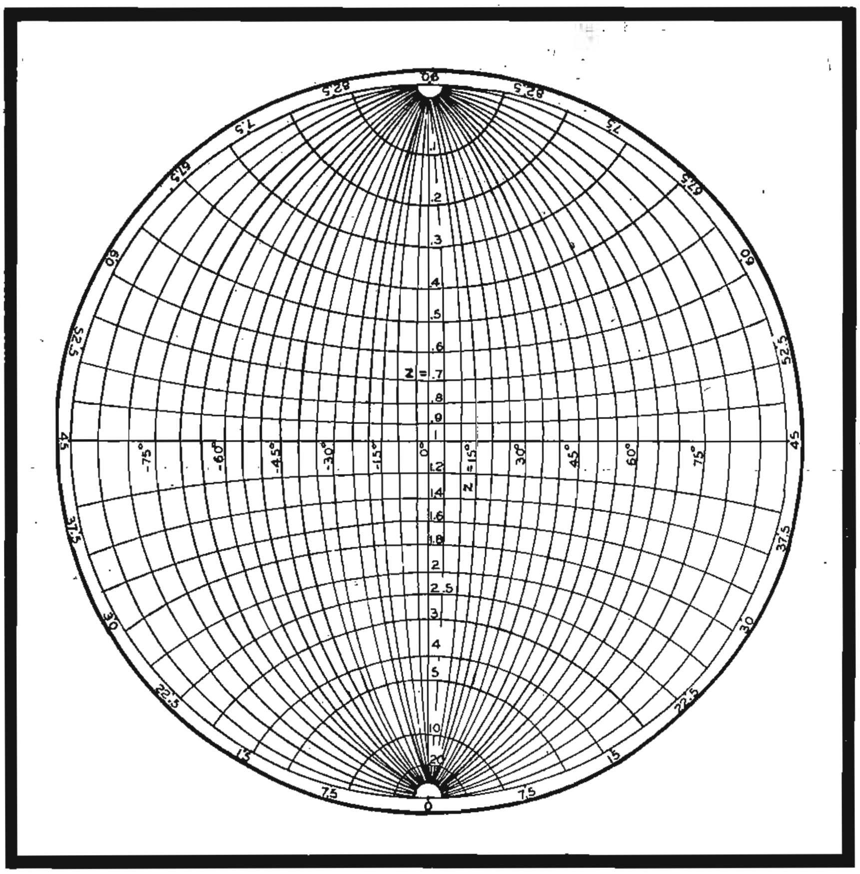
Leading design, manufacturing and operations engineers keep posted on all new developments in this fast-moving industry by reading COMMUNICATIONS every month. It has helped them. It can help you.

You and your associates can obtain a year's subscription to COMMUNICATIONS (12 issues) for only **$1.00** each by using the Group Subscription Plan. Here's how:

A regular yearly subscription to COMMUNICATIONS costs $2.00—but, when four or more men sign up at one time, each one is entitled to the half-price rate. (Foreign subscribers only pay **$2.00** each.)

It is easy to get three or more of your associates to subscribe with you. Thousands of leading engineers and executives have subscribed year after year on that basis. Use the convenient form on this page. Fill in the names, tear out and mail today with your check or money-order. Renewals and extensions are acceptable also.

COMMUNICATIONS • **52 Vanderbilt Ave., New York 17, N. Y.**



Carter chart

correspond to the three input impedances A_w, B_w, C_w (Figure 8). The two circles drawn through $A_z B_z C_z$ and $A_w B_w C_w$ will correspond to each other. To find the input impedance for another given load D_z we draw a circle K_z through $A_z B_z D_z$, and note the angle of intersection between the two circles. We then draw the corresponding circle K_w in the *w* plane through $A_w B_w$ with the same angle of intersection. The procedure is repeated with a circle K'_z through $A_z C_z D_z$ obtaining K'_w. The point of intersection of K_w and K'_w gives D_w.

In the case of a lossless quadripole we know that a reactive load will furnish a reactive input. That is, points on the imaginary *x* axis will map onto the imaginary *v* axis. Therefore with only two pair of corresponding points, $A_z B_z$ and $A_w B_w$, we find one more pair by drawing those circles through $A_z B_z$ and $A_w B_w$, which intersect the imaginary axis with 90°. The points of intersection again correspond to each other. The construction of other corresponding points then proceeds as in Figure 8.

Example of Application

Let us now try to find graphically the input impedance of the network given in Figure 9.

It consists of three lines $L_1 L_2$ and L_3 in series connection. Their respective characteristic impedance is $Z_1 Z_2 Z_3$, respective lengths $\theta_1 = 120°$, $\theta_2 = 180°$, $\theta_3 = 60°$. Line L_2 is supposed to be terminated by a matched load, $R_2 = Z_2 = 50$ ohms, which makes its input impedance at point *B* also equal to 50 ohms. Now, assuming that $Z_3 = 25$ ohms and the load of line L_3, consisting of a resonant circuit with a parallel resistance R_p equal to $R_p = Z_3$, this line is properly matched if the circuit is tuned to resonance. The input impedance into line Z_3 then is equal to $R_3 = 25$ ohms. If we chose $Z_1 = Z_2 + Z_3 = 75$ ohms, the input impedance of the whole system at point *A* will equal 75 ohms, since line L_1 will be matched also.

Our problem concerns the input impedance at *A* for the cases: (*1*) Varying the tuning of the resonant circuit and (*2*) varying the value of R_p, at resonance.

As in both cases, line Z_2 remains matched, we have to analyze the circuit of Figure 10.

We must: (*a*)—Find the impedance of the resonant circuit, (*b*)—find the input impedance of L_3, (c)—add a constant resistance of 50 ohms, (*d*)—divide by three, because of the changing characteristic impedances (this step is indicated by a lossless transformer *T*), and (*e*)—find the input impedance of line L_1.

The admittance of the resonant circuit is

$$Y = \frac{1}{R_p} + j\left(\omega C - \frac{1}{\omega L}\right)$$

which we can transform into

$$Y = \frac{1}{R_p}(1 + js)$$

where: *s* is the normalized detuning

$$s = Q \cdot \epsilon$$

$$Q = \frac{R_p}{\omega_o L} \text{ (Q of the resonant circuit)}$$

$$\epsilon = \frac{\omega}{\omega_o} - \frac{\omega_o}{\omega} \text{ (detuning)}$$

f_o = the resonant frequency

$\omega_o = 2\pi f_o$

The impedance then is

$$Z = R_p \frac{1}{1 + js},$$

and if referred to the characteristic impedance of line, L_3,

$$z = \frac{Z}{Z_3} = \frac{1}{1 + js}$$

This represents the inversion of a vector $y = 1 + js$, the end point of which, in a complex *y*-plane, glides along a parallel K_y to the imaginary axis, through the point $y_o = +1$, Figure 11.

Its inversion, in accordance with Figure 6, is a circle K_z of unit diameter normal to the real axis.

At a certain detuning, the vector *z*

(*Continued on page* 53)

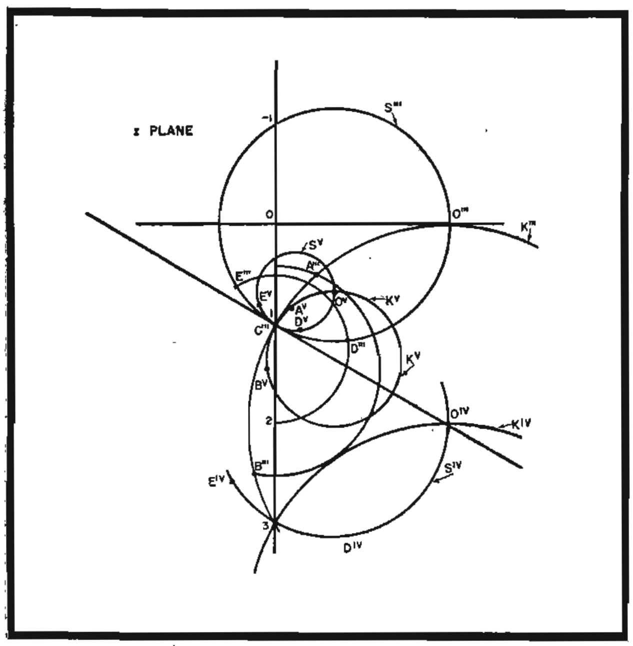


Figure 13
Solution of example in the *z* plane (impedance plane).

Simplified INPUT IMPEDANCE CHART for Lossless Transmission Lines*

by LEONARD MAUTNER

Research Engineer
Allen B. Du Mont Laboratories

Chart Offers Rapid Appraisal of Input Impedance of Line Lengths Commonly Used for Various Types of Terminations.

CALCULATIONS involving transmission lines whose loss is negligible are most conveniently carried out by the use of impedance circle diagrams or the Smith chart. For those who are not too familiar with these diagrams, a simplified chart of input impedances (Figure 1) has been prepared.

The input impedance of a lossless transmission line of any length is

$$\mathbf{Z}_s = Z_o \frac{\mathbf{Z}_r + jZ_o \tan \beta l}{Z_o + j\mathbf{Z}_r \tan \beta l} \qquad (1)$$

Where: $\mathbf{Z}_s$ = input impedance
Z_o = characteristic impedance
$\mathbf{Z}_r$ = load impedance
β = phase constant = $\frac{2\pi}{\lambda}$
l = line length in terms of wavelength

Thus $\beta l = k(2\pi)$, k being the length of the line in fractions of a wavelength.

Equation (*1*) may be written then as

$$\mathbf{Z}_s = Z_o \frac{\mathbf{Z}_r + jZ_o \tan(2\pi k)}{Z_o + j\mathbf{Z}_r \tan(2\pi k)} \qquad (2)$$

The particular line lengths that are of most interest are those where the value of tan $(2\pi k)$ takes on special values. Since the values of $\tan\frac{\pi}{4}$, $\tan\frac{\pi}{2}$, $\tan\frac{3\pi}{8}$, and $\tan \pi$ give +1, ∞, −1 and 0 respectively, the corresponding line lengths and values of k are:

$$2\pi k = \frac{\pi}{4} \quad ; \quad k = \frac{1}{8}$$

$$2\pi k = \frac{\pi}{2} \quad ; \quad k = \frac{1}{4}$$

$$2\pi k = \frac{3\pi}{8} \quad ; \quad k = \frac{3}{8}$$

$$2\pi k = \pi \quad ; \quad k = \frac{1}{2}$$

But the tangent function repeats after π, so the special line lengths become

Line length in wavelengths	*Value of* $2\pi k$
$\frac{1}{8}, \frac{5}{8}, \frac{9}{8}, \ldots \frac{4n+1}{8}$	+1
$\frac{1}{4}, \frac{3}{4}, \frac{5}{4}, \ldots \frac{2n+1}{4}$	∞
$\frac{3}{8}, \frac{7}{8}, \frac{11}{8}, \ldots \frac{4n-1}{8}$	−1
$\frac{1}{2}, 1, \frac{3}{2}, \ldots \frac{n}{2}$	0

Where n is an integer as 1, 2, 3, . . .

Considering the case where $k = \frac{1}{2}$, equation (*1*) becomes

$$\mathbf{Z}_s \Big]_{k=\frac{1}{2}} = Z_o \frac{\mathbf{Z}_r}{Z_o} = \mathbf{Z}_r \qquad (3)$$

Thus a half-wavelength line with any termination has an input impedance equal to the load impedance, or acts as a one to one transformer.

When $k = \frac{1}{4}$, $\tan \beta l = \infty$, and it is convenient to divide by $\tan\beta l$ before evaluating $\mathbf{Z}_s$. Thus

$$\mathbf{Z}_s = Z_o \frac{\frac{\mathbf{Z}_r}{\tan \beta l} + jZ_o}{\frac{Z_o}{\tan \beta l} + j\mathbf{Z}_r} \qquad (4)$$

for $k = \frac{1}{4}$, then

$$\mathbf{Z}_s \Big]_{k=\frac{1}{4}} = Z_o \frac{jZ_o}{j\mathbf{Z}_r} = \frac{Z^2_o}{\mathbf{Z}_r} \qquad (5)$$

A quarter-wavelength line is then an impedance transformer; if $\mathbf{Z}_r$ is a large resistance, then $\mathbf{Z}_s$ is a small resistance, and vice versa. In addition, if $\mathbf{Z}_r = jZ_r$, then $\mathbf{Z}_s = -jZ^2_o/Z_r$, or an inductive termination appears as a capacitance at the sending end.

When $k = \frac{1}{8}$, equation (*1*) can be written as

$$\mathbf{Z}_s \Big]_{k=\frac{1}{8}} = Z_o \frac{Z_r + jZ_o}{Z_o + jZ_r} \qquad (6)$$

Rationalizing gives,

$$\mathbf{Z}_s \Big]_{k=\frac{1}{8}} = Z_o \frac{(Z_r + jZ_o)(Z_o - jZ_r)}{Z^2_o + Z^2_r} \qquad (7)$$

$$= Z_o \frac{2Z_o Z_r + jZ^2_o - jZ^2_r}{Z^2_o + Z^2_r}$$

$$= Z_o \frac{2Z_o Z_r + j(Z^2_o - jZ^2_r)}{Z^2_o + Z^2_r} \qquad (8)$$

The magnitude of $\mathbf{Z}_s$ for $k = \frac{1}{8}$ is then seen to be

$$Z_s \Big]_{k=\frac{1}{8}} = Z_o \frac{\sqrt{(2Z_oZ_r)^2 + (Z^2_o - Z^2_r)^2}}{Z^2_o + Z^2_r}$$

$$= Z_o \qquad (9)$$

And the phase angle is

$$\phi = \tan^{-1} \frac{Z^2_o - Z^2_r}{2Z_o Z_r}$$

$$= \tan^{-1} \frac{1}{2}\left(\frac{Z_o}{Z_r} - \frac{Z_r}{Z_o}\right) \qquad (10)$$

Hence an eighth-wavelength line with a *resistance* termination appears to be an impedance whose magnitude is always Z_o, as viewed from the sending end, but whose phase is dependent on the magnitude of the terminating resistor. If the termination is induc-

(*Continued on page* 63)

**From a book on "Mathematics for Radio Engineers" by Mr. Mautner, to be published soon by the Pitman Publishing Corporation, New York City.*

LENGTH OF LINE	INPUT IMPEDANCE VECTOR $Z_s = Z_s \angle\theta$	RESISTIVE LOAD $Z_r = Z_r \angle 0° = Z_r$				INDUCTIVE LOAD $Z_r = Z_r \angle +90° = +jZ_r$				CAPACITIVE LOAD $Z_r = Z_r \angle -90° = -jZ_r$			
		SIMPLIFIED Z_s	MAGNIT. OF Z_r	CORRESPONDING MAGNIT. Z_s	CORRESPONDING PHASE θ	SIMPLIFIED Z_s	MAGNIT. OF Z_r	CORRESPONDING MAGNIT. Z_s	CORRESPONDING PHASE θ	SIMPLIFIED Z_s	MAGNIT. OF Z_r	CORRESPONDING MAGNIT. Z_s	CORRESPONDING PHASE θ
$\frac{n}{2}\lambda$	Z_r	Z_r	0 $< Z_0$ $= Z_0$ $> Z_0$ ∞	0 $< Z_0$ $= Z_0$ $> Z_0$ ∞	0° 0° 0° 0° 0°	$Z_r \angle +90° = jZ_r$	0 $< Z_0$ $= Z_0$ $> Z_0$ ∞	0 $< Z_0$ $= Z_0$ $> Z_0$ ∞	+90° +90° +90° +90° +90°	$Z_r \angle -90° = -jZ_r$	0 $< Z_0$ $= Z_0$ $> Z_0$ ∞	0 $< Z_0$ $= Z_0$ $> Z_0$ ∞	-90° -90° -90° -90° -90°
$\frac{2n+1}{4}\lambda$	$\frac{Z_0^2}{Z_r}$	$\frac{Z_0^2}{Z_r}$	0 $< Z_0$ $= Z_0$ $> Z_0$ ∞	∞ $> Z_0$ $= Z_0$ $< Z_0$ 0	0° 0° 0° 0° 0°	$\frac{Z_0^2}{Z_r} \angle -90° = -j\frac{Z_0^2}{Z_r}$	0 $< Z_0$ $= Z_0$ $> Z_0$ ∞	∞ $> Z_0$ $= Z_0$ $< Z_0$ 0	-90° -90° -90° -90° -90°	$\frac{Z_0^2}{Z_r} \angle +90° = +j\frac{Z_0^2}{Z_r}$	0 $< Z_0$ $= Z_0$ $> Z_0$ ∞	∞ $> Z_0$ $= Z_0$ $< Z_0$ 0	+90° +90° +90° +90° +90°
$\frac{4n+1}{8}\lambda$	$Z_0\frac{Z_r + jZ_0}{Z_0 + jZ_r}$	$Z_0 \angle \tan^{-1}\left(\frac{Z_0}{Z_r} - \frac{Z_r}{Z_0}\right)\frac{1}{2}$	0 $< Z_0$ $= Z_0$ $> Z_0$ ∞	Z_0 Z_0 Z_0 Z_0 Z_0	+90° POS. 0° NEG. -90°	$Z_0\frac{Z_r + Z_0}{Z_0 - Z_r} \angle +90° = +jZ_0\frac{Z_r + Z_0}{Z_0 - Z_r}$	0 $< Z_0$ $= Z_0$ $> Z_0$ ∞	Z_0 $> Z_0$ ∞ $> Z_0$ Z_0	+90° +90° ±90° -90° -90°	$Z_0\frac{Z_r - Z_0}{Z_0 + Z_r} \angle -90° = -jZ_0\frac{Z_r - Z_0}{Z_0 + Z_r}$	0 $< Z_0$ $= Z_0$ $> Z_0$ ∞	Z_0 $< Z_0$ 0 $< Z_0$ Z_0	+90° +90° ±90° -90° -90°
$\frac{4n-1}{8}\lambda$	$Z_0\frac{Z_r - jZ_0}{Z_0 - jZ_r}$	$Z_0 \angle \tan^{-1}\frac{1}{2}\left(-\frac{Z_0}{Z_r} + \frac{Z_r}{Z_0}\right)$	0 $< Z_0$ $= Z_0$ $> Z_0$ ∞	Z_0 Z_0 Z_0 Z_0 Z_0	-90° NEG. 0° POS. +90°	$Z_0\frac{Z_r - Z_0}{Z_0 + Z_r} \angle +90° = +jZ_0\frac{Z_r - Z_0}{Z_0 + Z_r}$	0 $< Z_0$ $= Z_0$ $> Z_0$ ∞	Z_0 $< Z_0$ 0 $< Z_0$ Z_0	-90° -90° ∓90° +90° +90°	$Z_0\frac{Z_r + Z_0}{Z_0 - Z_r} \angle -90° = -jZ_0\frac{Z_r + Z_0}{Z_0 - Z_r}$	0 $< Z_0$ $= Z_0$ $> Z_0$ ∞	Z_0 $> Z_0$ ∞ $> Z_0$ Z_0	-90° -90° ∓90° +90° +90°

Figure 1
Chart of input impedance of a lossless line for special line lengths and load impedances.

Oldtimers who were at the recent dinner-cruise at the Hotel Astor in New York, left to right: Jack Poppele, Dr. F. B. Llewellyn, George Adair, Sam Schneider, Arthur Lynch, Pete Podell, General David Sarnoff, Arthur Batcheller, and Benny Beckerman.

CONGRATULATIONS to life member General David Sarnoff on receiving a second Legion of Merit Medal from the President. . . . Bill Simon continues his grand job of handling the detailed work of our association. He deserves a vote of thanks for the longest tenure in office as executive secretary. Keep up the good work, Bill. . . . George H. Clark, now that he has a little more freedom, spends considerable time at his summer home in New Jersey. . . . An application for membership has recently been forwarded to Colonel E. C. Page, vice president in charge of engineering of the Mutual Broadcasting System, an old-time operator who distinguished himself in World War II.

. . . Captain Wilbur C. Roberts, of the Army Air Forces at Langley Field, Virginia, makes his permanent home in Rockdale, Texas. . . . Charles E. Williams, who was a commercial operator back in 1915, now residing in Seattle, Wash., has applied for membership in VWOA. . . . It is now Captain Fred Muller, attached to the 16th Fleet based at New York. Hearty congratulations, Fred, from all the old-timers, on achieving the fourth stripe.

. . . Because of conditions beyond control, veteran member Martell E. Montgomery, Servicos Aereos Cruzeiro do Sul, Ltda., Rio de Janeiro, was unable to attend the recent dinner-cruise at the Astor. . . . The twenty-second anniversary dinner-cruise will be held at the Hotel Astor in February, 1947. Make your reservations now. . . . Old-timer R. C. Reinhardt, president of the Atlas Sound Corporation, has applied for VWOA membership. . . . Paul K. Trautwein, a former treasurer of our association, is becoming increasingly active in VWOA affairs.

. . . 'Steve' Wallis is back in New York and we were certainly happy to have had him with us at the Astor. . . . Veteran member Commander Samuel Freedman is now stationed at the Navy Electronics Laboratory at San Diego, Calif. He is the author of the book *Two-Way Radio*. . . . George C. Coffin is now with the Department of Transport, Montreal Aeradio at Montreal Airport, in charge of transmitter layout and construction. . . . Prexy 'Bill' McGonigle is now conducting a radio school in the New York Telephone Company. . . . Major Le Roy Thompson, Jr., radio engineer HQ SSU, is a recent applicant for membership. . . . Welcome to our ranks, Lt. Commander B. Frank Borsody, U. S. N. R. By the way, Commander Borsody won the Hallicrafters SX28A receiver at the dinner-cruise in February.

. . . George J. Maki was recently relieved from active Signal Corps duty as a Captain. He's now at Collins Radio, Cedar Rapids, Iowa, specializing in radiotelegraph systems development. . . . Lt. Robert L. Willits, active as a Radio Officer in the Merchant Marine, recently became a VWOA member. . . . Congress has passed a bill officially designating radio personnel aboard merchant vessels as Officers.

. . . With regret we announce the death of veteran member Charles H. Stoup.

. . . L. C. Herndon, Inspector in Charge of the 14th District, has dropped us a note saying: "I transferred to Seattle in 1935 and as a result lost contact with many of the fellows and let my membership lapse; however each issue of COMMUNICATIONS brings word of someone I know and things VWOA is doing, and in a sense I feel I am still in the fold. Please send me the necessary papers so that I may again become active in VWOA affairs." . . . Ralph C. Folkman, in radio with the Cleveland, Ohio, police department for the past sixteen years, went to sea as a commercial operator from 1922 to 1928. . . . Commander Edwin W. Lovejoy, U. S. N. R., a happy participant at our 21st annual, is stationed at the Philadelphia Navy Yard. . . . Since January 1st, 1946, veteran member Ed G. Raser, W3ZI, has been director of the Atlantic Division of the American Radio Relay League. A real pioneer in wireless, Ed is also secretary of the Delaware Valley Radio Association. Veteran member G. Brock Angle of Hialeah, Florida, now publishes *Hobbysway Contacts*, a publication for hobbyists. . . . Welcome to Walter Jablon, sales engineer of the Hammarlund Manufacturing Company, into the ranks of our veteran members. . . . A hearty welcome, too, to Captain George F. Shecklen, U. S. N. R., executive vice president of the Radiomarine Corporation of America. Captain Shecklen won the National Company NC 240 receiver at the Astor dinner-cruise. . . . Fred McDermott, a career Chief Radioman in the U. S. Navy, returned to the service for the duration. He did a very creditable job. He has recently returned to his post with the American Telephone and Telegraph Company in the program transmission department. . . . Lt. Preston L. Stocum, formerly stationed at Fort Monmouth, is now at Klamuth Falls, Oregon. . . . Lt. E. K. Price is at Naval Air, Floyd Bennett Field, N. Y. . . . Lt. J. Vanderhoff, of the U. S. Marine Corps, receives his mail through the FPO, San Francisco. . . . J. R. Arkinstall is at the New York State Maritime Academy at Fort Schuyler, N. Y. . . . Chief Radioman C. R. Spicer now has a permanent address in San Francisco, Calif. . . . Lt. F. T. Bowen is now on staff of CinCPac, working out of San Francisco.

BOOK TALK . . .

NETWORK ANALYSIS AND FEEDBACK AMPLIFIER DESIGN

By *Hendrik Bode*, Ph.D., Research Mathematician, Bell Telephone Laboratories Inc. . . . 551 pp. . . . New York: D. Van Nostrand Co. . . . $7.50

Dr. Bode's book is the outgrowth of a series of lectures presented at the Bell Telephone Laboratories some years ago. Originally planned as a text exclusively on the design of feedback amplifiers, the addition of new material shifted emphasis until the book became primarily one on general network theory. Dr. Bode's approach throughout is mathematical; his assumption is that the reader has a thorough grounding in electrical and mathematical theory.

In the initial chapters Dr. Bode offers a comparison between the mesh and nodal systems of analysis of which Kirchoff's laws are an expression. Of the two, the nodal system appears to be better adapted to complicated high-frequency circuits where ground capacities may considerably increase the number of meshes. Dr. Bode points out that, although engineering applications are concerned with circuit response to currents and voltages at real frequencies, the assumption of a *complex* frequency, that is, a frequency with real and imaginary components, may facilitate mathematical treatment. After exploring the physical nearing of the *complex* frequency, several chapters are devoted to an analysis of feedback circuits and the development of a general theory in terms of the mesh and nodal equations.

Having described the mathematical tools needed for active network analysis, for the study of actually existing networks, Dr. Bode goes on to the inverse problem of designing networks to conform to desired characteristics. Generally, more than one solution is possible, and the problem is one of ascertaining at the beginning of a design, which combination may be excluded. The criteria that must be met are: (*a*) stability, in the case of active vacuum-tube structures and, (*b*) that passive circuits consist of positive elements of resistance, inductance and capacitance.

The final portion of the book covers a number of particular problems that are handled by the general methods described earlier. The design of input or output transformers terminated in an open circuit (except for a specified parasitic shunt capacity) and the design of such transformers terminated in a finite resistance are considered.

Dr. Bode's book is thorough and scholarly. It should prove of value to designing engineers engaged in theoretical calculations.

NEWS BRIEFS

P. M. HONNELL JOINS U. OF ILL.

Lieut. Colonel P. M. Honnell, director of the electronics laboratory at the U. S. Military Academy, West Point, N. Y., has joined the staff of Dr. W. L. Everitt at the University of Illinois.

* * *

GERMAN QUARTZ CRYSTAL PRODUCTION REPORT

A report on German synthetic quartz crystals based on interviews with German researchers, has been released by the Office of the Publication Board, Department of Commerce.

The report was made by G. E. Guellich, John White, and C. B. Sawyer, investigators for the Joint Intelligence Objectives Agency.

One German method involved use of alkali halide crystals, derived from specially purified salts, as prisms in the ultraviolet monochromators. Use of pure salts reduced the crystals' sensitivity to water vapor.

The prisms were always mounted on slightly heated tables to prevent fogging. Crystallization occurred from the top of the molten salt downward.

To initiate the process, a small piece of salt was mounted in a water-cooled holder and lowered until it touched the top surface of the molten salt, contained in a porcelain crucible. The water-cooling caused the crystal to grow. As it became larger, the crystal was raised slightly, to permit continuing growth. Finally, the crystal was removed and placed in an annealing oven at 500° C for 24 hours, after which it was cooled for four or five days. Crystals produced in this way are said to be as homogeneous as good optical glass.

* * *

SPECIALISTS NEEDED FOR GERMAN INDUSTRY STUDY

Communications personnel qualified for the work of searching German files are now needed by the Commerce Department. Routine work will be done by German civilians but qualified American technicians are indispensable for the all important job of supervision and selection.

Appointments are subject to Civil Service approval and are made for a minimum of six months.

Any industry or scientific group interested in specific German industrial methods and able to assign personnel to visit Germany should contact John C. Green, executive secretary, Office of the Publication Board, Department of Commerce, Washington 25, D. C.

* * *

CINCINNATI RADIO-TELE INSTITUTE PLANNED

The first annual Radio-Television Summer Institute will be conducted by WLW and the College of Music of Cincinnati from June 17 to July 27.

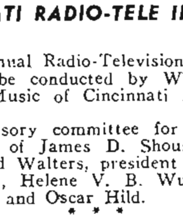
The advisory committee for the institute is composed of James D. Shouse, chairman; Dr. Raymond Walters, president of University of Cincinnati, Helene V. B. Wurlitzer, Louis F. Schlueter and Oscar Hild.

* * *

SYLVANIA NAMES BISHOP DIRECTOR OF SALES

Robert H. Bishop has been named director of sales for all divisions and subsidiaries of Sylvania Electric Products, Inc.

Mr. Bishop will be responsible for the coordination of selling policy in all divisions of the company as well as its subsidiaries, Colonial Radio Corporation and Wabash Corporation.



* * *

REINARTZ RETURNS TO RCA FROM NAVY

Captain John L. Reinartz, who was recently released from the U. S. Navy after serving seven years as communications and electronics officer, has returned to RCA. He has been assigned to the commercial engineering and power tube sections, in charge of the amateur radio program, at the Lancaster, Pa., plant.

* * *

WESTINGHOUSE SIGNS ARMSTRONG F-M LICENSES

Armstrong patents will be incorporated in the full Westinghouse f-m home receiver and commercial line under a licensing agreement with Major Edwin H. Armstrong.

* * *

J. F. RIDER BECOMES RCA TEST EQUIPMENT CONSULTANT

Lt. Col. John F. Rider has been retained by RCA Victor as a consultant on test equipment. Col. Rider will work in cooperation with the test and measuring equipment section.

* * *

FCC ANNUAL REPORT AVAILABLE

The FCC eleventh annual report for the fiscal year ended June 30, 1945, is now available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., at 20 cents a copy.

* * *

MICHIGAN TELEPHONE CO. PLANS RADIO TOLL SERVICE

The Union Telephone Company, Owosso, Michigan, has filed an application for an experimental radiotelephone channel to supplement wire toll lines between its exchanges at Owosso and Mount Pleasant, 75 miles apart.

Links will provide three two-way conversation channels, which may be used simultaneously, without interference with each other and with complete secrecy. Facilities will also be provided for direct dialing "over the air" so that dial telephones at Mount Pleasant may be reached by the operator at Owosso without help from a terminating operator.

* * *

HOWARD SAMS BEGINS CIRCUIT-ANALYSIS SERVICE

A radio encyclopedia service has been inaugurated by the Howard W. Sams & Co., Inc., 2924 E. Washington St., Indianapolis, Ind.

The service will be issued periodically in the form of "PhotoFact" folders, each folder covering one receiver model. The folders will vary in size from 4 pages to 12 pages, and will be illustrated and contain lists of parts and suitable replacements as well as detailed engineering data and voltage and resistance analysis.

These folders will be sent to users of the service in folios of 30 to 50 at frequent intervals.

According to Mr. Sams, new receivers will be analyzed, components will be checked, and resistance and voltage values will be recorded. "PhotoFact" folders will cover receivers placed on the market after January 1, 1946.

* * *

CONLAN OFFERS COMPLETE TRANSMITTING STATION SERVICE

A design, engineering, production and installation service for those planning a-m, f-m and television installations, has been announced by the design and engineering division of the Conlan Electric Corporation, 1042 Atlantic Avenue, Brooklyn 16, N. Y.

Ira Kamen, formerly supervisory engineer of the Field Section, Navy Yard, New York, is chief electronics engineer.

* * *

MAJOR ROBINSON JOINS MOTOROLA

Major Robinson has been appointed radio communications engineer for Motorola.

* * *

PHILIPS TECHNICAL REVIEW RESUMES PUBLICATION

The "Philips Technical Review," which was published monthly before the war by the research Laboratory of N. V. Philips Gloeilampenfabrieken of Eindhoven, Holland, has resumed publication.

Subscriptions for the Review are being handled in this country by Elsevier Publishing Company, 215 Fourth Avenue, New York.

* * *

SHALLCROSS ACQUIRES CINEMA ATTENUATOR

Shallcross Manufacturing Co., Collingdale, Pa., has acquired the manufacturing rights and licenses to produce Variaten attenuators, gain sets, and other resistance devices manufactured by the Cinema Engineering Co., Burbank, Calif.

Cinema Engineering Co. will serve as field engineers for Shallcross Mfg. Co. on the combined product lines, in the southwestern states.

* * *

CHERTOK BECOMES SOLAR AD MANAGER

Sidney L. Chertok has been named advertising manager of the Solar Manufacturing Corporation. Mr. Chertok, who has been manager of Solar's technical service bureau, will also act as advertising manager of the Solar Capacitor Sales Corporation. He succeeds S. A. Wolin, resigned.

* * *

WAGENER JOINS EIMAC

Winfield Wagener has been appointed to the sales engineering staff of Eitel-McCullough, Inc., San Bruno, California, manufacturers of radio transmitting tubes.

He was formerly chief engineer of Heintz & Kaufman in charge of all tube development and design.

* * *

FARNSWORTH PROMOTIONS

Paul J. Boxell has been named director of public relations for the Farnsworth Television & Radio Corporation.

Mr. Boxell succeeds Captain Pierre Boucheron who has been named manager of the

(*Continued on page 50*)

NEWS BRIEFS

(*Continued from page 49*)

Farnsworth broadcast division and radio station WGL, Fort Wayne.

William T. Davies has been appointed assistant to the general manager of the Farnsworth broadcast division and WGL.

C. Murray Leeds, formerly with Thomas A. Edison Incorporated and the Wright Aeronautical Corporation, has joined the staff of the mobile communications division of Farnsworth.

Philips B. Patton, formerly with the FCC, has also joined the mobile communications staff of Farnsworth.

P. Boxell (left, top)
P. B. Patton (top)
C. M. Leeds (left)

* * *

WOLIN JOINS PYRAMID ELECTRIC

Sylvan A. Wolin, formerly with Solar Manufacturing Corp., has joined the Pyramid Electric Co., 415 Tonnele Avenue, Jersey City, N. J., manufacturers of electrolytic capacitors and noise eliminators.

* * *

SOLAR SYSTEM BI-MONTHLY

The first issue of the "Solar System," a bi-monthly devoted to capacitor application analyses and allied subjects, has been published by the Solar Manufacturing Corporation, 285 Madison Avenue, New York City.

Featured in the first issue are articles on the proximity fuze, capacitor-type a-c follow-up motor, RMA color code and the Army-Navy color code.

S. L. Chertok is editor of the magazine.

* * *

HUTCHENS, EDITOR OF RCA "RELAY," DEAD

Raymond D. Hutchens, editor of "Relay," a publication of RCA Communications, Inc., died recently. He was 41.

* * *

G. R. PRICE LIST

A price list for catalog K has been released by the General Radio Company, 275 Massachusetts Avenue, Cambridge 39, Mass.

* * *

HERBACH AND RADEMAN CATALOG

A 16-page catalog describing decade resistances, variable frequency electronic generators, 75-watt transmitters, frequency deviation meters, portable electric megaphones, non-radiating receivers, etc., has been published by the manufacturing division of Herbach and Rademan Company, 517 Ludlow Street, Philadelphia, Pa.

* * *

G. E. RECEIVING TUBE BOOKLETS

Two 40-page booklets with characteristics and ratings of G. E. and Ken-Rad receiving tube types have been released by the tube division of G. E.

The new brochures cover: interpretation of ratings and technical data; recommended types; characteristics and ratings; and outline drawings and basing connections.

* * *

ELECTRO-VOICE CARDAX CARDIOID CRYSTAL MICROPHONE BULLETIN

A 4-page bulletin on the model 950 Cardax cardioid unidirectional crystal microphone has been issued by Electro-Voice, Inc., 1239 South Bend Ave., South Bend 24, Indiana.

Data offered includes frequency response curves, applications, etc.

* * *

DONALD G. HAINES JOINS HYTRON

Donald G. Haines has been appointed sales and commercial engineer of Hytron Radio and Electronics Corp., Salem, Mass. He will be located at 4000 West North Avenue, Chicago.

* * *

SISSON BECOMES BELL SOUND CHIEF ENGINEER

Edwin D. Sisson has been appointed chief engineer of the Bell Sound Systems, Inc., 1183 Essex Ave., Columbus, Ohio.

* * *

J. L. VETTE, JR., BUYS SNC MFG. CO.

John L. Vette, Jr., has purchased the controlling interest in the SNC Manufacturing Company, located in Glenview, Illinois.

Jack Beebe will continue as general sales manager. William R. Daseke remains as chief of the engineering division.

* * *

OHMITE LITTLE DEVIL RESISTOR DATA

A 4-page bulletin No. 127, describing and illustrating ½-watt, 1-watt, and 2-watt insulated composition resistors, has been released by Ohmite Manufacturing Company, 4835 Flournoy Street, Chicago 44, Illinois.

* * *

PANADAPTOR HANDBOOK

A 36-page handbook describing the design and application of the Panadaptor, has been released by the Panoramic Radio Corporation, 242 West 55 Street, New York 19, N. Y.

Featured in the handbook are circuit details, typical c-r tube patterns and installation notes. The handbook is available at 50 cents a copy.

TRANSMISSION LINES

(*Continued from page* 25)

optimum values. For the optimum proportions equation (*13*) becomes

$$Z_s = \frac{11.11\sqrt{f}\,b}{n} \qquad (15a)$$

for the coaxial line, and

$$Z_s = \frac{23.95\sqrt{f}\,b}{n} \qquad (15b)$$

for the parallel line. In these equations b is in centimeters and f is in cycles per second.

The Q of the lines may be computed from the relation

$$Q = \frac{2\pi Z_o f}{R c} \qquad (16)$$

This is also a function of b/a, but is a maximum for $b/a = 3.6$ for the coaxial line, and approximately this for the parallel type. For optimum proportions (*16*) becomes

$$Q = .0839\sqrt{f}\,b \qquad (17a)$$

for the coaxial line, and

$$Q = .0887\sqrt{f}\,b \qquad (17b)$$

for the other. It will be noted that the optimum ratio for Q is not the same as that for Z_s. If the best value is used for Q, the values of Z_s computed by (*15a*) and (*15b*) should be multiplied by .72 and .75 respectively[4]. Correction factors for other values of b/a may be found in the reference.

As an example let us compute the dimensions and characteristics of a line to be used as the grid tank of a high-frequency oscillator operating at 200 mc. In such an application Q should be high, so we shall design for maximum Q using a coaxial line; hence b/a is 3.6. The use of the coaxial line prevents radiation losses which would lower the effective Q (such losses have been neglected in deriving our equations). A short-circuited line will be a quarter-wave-length long, so n is unity and the length is 1.5/4 meters or 14.75″.

If we assume b is 1″, then a is 1/3.6 or .278″. Hence

$$Q = .0839\sqrt{2 \times 10^8} \times 2.54 = 3{,}000$$

which is very much higher than could have been obtained with conventional circuits and which compares favorably

[4]Terman, F. E., Radio Engineers Handbook; p. 191.

(*Continued on page* 52)

TRANSMISSION LINES

(*Continued from page* 51)

with crystals. Using equation (*15a*), the impedance is

$$Z_s = \frac{11.11\sqrt{2 \times 10^{8}} \times 2.54 \times .72}{1}$$

$$= 288{,}000 \text{ ohms}$$

A circuit utilizing this line is shown in Figure 4. The grid is connected to an intermediate point rather than at the open end to give as light a loading as is consistent with reliable oscillations. Appreciable loading of the line by the tube will lower the Q from the value computed above.

The impedance presented to the tube by a resonant line designed for a given Q may be varied by tapping the grid or plate connection towards the closed end of the line. When the line is tapped, as shown in Figure 4, it still presents a resonant circuit to the load. If the line has the correct length to give resonance at its end terminals, it will also appear resonant when connected at any other point, the inductive reactance of the line on one side of the tap point being exactly balanced by the capacitive reactance of the other side. This corresponds to the conventional resonant circuit behavior when the load is connected across only a part of the inductance in order to adjust the value of the impedance.

In certain applications open lines rather than short-circuited ones may be desirable, but in general short-circuited ones are preferrable as they give shorter lines and consequently higher values of Q. Resonant lines may be made adjustable in length where it is desired to tune them. Since the tube connections and elements introduce modifying inductances and capacitances some slight adjustment in length is often necessary. Coaxial or parallel lines may be used as convenient. The coaxial is not subject to radiation losses and hence will perform more closely as calculated. However, the open line is often more easily adjusted and sometimes easier to couple to.

Since a short-circuited line a quarter wavelength long presents a very high impedance at the open end it is often used as a r-f choke. The higher the Q the more effective it is, but the design is not critical. A line is shown in such an application in the cathode supply of Figure 5 (the short may be made by a capacitor of negligible reactance at the operating frequency). Another useful application is that of a support for the center conductor of a coaxial line. As shown in Figure 5*b* the center conductor is supported by quarter-wave stubs, thus giving good mechanical support with small losses.

The cathode supply of Figure 4 illustrates another application of lines. Here a half-wavelength line, short circuited by the capacitances, is used to connect the cathode to ground. This permits placing the cathode at ground potential (since both ends of the half wave line are at the same potential, as shown in Figure 1*a*) and avoids the reactance of the cathode leads.

An effect analogous to a resonant rise of voltage may be obtained by applying the generator to a low-voltage point and the receiver to a high voltage point. Thus, by reference to Figure 1, we see that with the receiver at the open end of the line there is a rise of voltage from the generator to the receiver, if the generator is connected at any odd quarter-wave point. Similar results may be obtained by the proper use of short-circuited lines.

4-TERMINAL NETWORKS

(*Continued from page 43*)

includes a 45° angle with the real axis; the two corresponding points are designated A and B. Together with the resonance point C they shall be followed up through the network.

All points corresponding to case **2**, of course, lie on the real axis and to specify also two more points we may take points D and E with $R_p/Z_3 = .5$ and 2 respectively.

To perform the transformation of z by the line we transfer the circle K_z into a Smith chart. (Figure 12). The points $A = .5 - j.5$ and $B = .5 + j.5$ and the points O, C, D and E are readily localized; the latter four lying on the real axis. They are designated O^1, A^1, B^1, C^1, D^1 and E^1. We may then draw the corresponding circle K^1 through O^1, A^1, B^1, and C^1. Now line L_a turns all points clockwise through twice 60° in the chart. Thus we obtain the circle K'', the straight line S'' and the points O'', A'', B'', C'', D'' and E''.

We can locate K'' and S'' back in the z plane, Figure 13. S'' goes through C'', the infinite point w_∞ and includes 60° with the positive real axis. The corresponding circle goes through the corresponding points $z = \pm 1$ under the same angle with the positive real z axis. Point O''' is the intersection with the imaginary axis. To find D''' and E''' we draw the auxiliary circle normal to the real axis through $z = .5$ and $z = 2$, which intersects S''' in D''' and E'''.

Circle K'' goes through C'' and O'' and intersects S'' under 90°. We therefore can draw K''' immediately. A''' and B''' lie on an auxiliary circle through $z = .39$ and $z = 2.56$ normal to the real axis. The addition of a constant resistance R_2 = 50 ohms amounts to pushing both S''' and K''' in the downward direction by an amount of $R_2/Z_3 = 50/25 = 2$, thus giving circles S^{IV} and K^{IV}.

The lossless transformer means a contraction of all Z vectors in the ratio of 3:1, which furnishes circles S^V and K^V.

We then transfer S^V and K^V back to the Smith chart. The position of C^{VI} is that of C^1. The angles of intersection with the real axis of K''' and K^V and of S''' and S^V have not changed. We can then draw S^{VI} and K^{VI} if we locate just one more point $O^V = .675 + j.575$ in the Smith chart. On the two circles we locate points A^{VI} B^{VI} D^{VI} and E^{VI}.

The transfer of particular points is completed easily, if we use a complete Smith chart, Figure 12. We then just read the components of a point in the z-plane and locate it on the chart (where the z plane coordinate system is reproduced). Otherwise we may use the methods outlined for Figures 2 and 4, in the latter case using the absolute value and phase angle of z.

If three points are already located we may use the method shown for Figure 8. In general the transfer of points from one plane into the other is not difficult.

Line L_1 now turns all points and both circles through twice the line length or 240°, clockwise, in the Smith chart, arriving at the dashed circles S^{VII} and K^{VII} which allow us to read off directly the input impedances of the whole system. Thus our problem is solved.

RAILROAD F-M SATELLITE SYSTEM

(Continued from page 21)

volt dynamotor was used in this instance to provide plate and filament voltages.

The antenna on the steam locomotive was of an experimental *cartwheel* ground-plane type. This was mounted on the tender of the steam engine, where the transmitter and receiver were located in an air-tight metal case. The antenna on the Diesel-electric was of a new, low-clearance type developed for railroad service, and was mounted on the motor hood, near the front of the locomotive. The total height of this antenna, when installed, was less than 11", above the top of the motor hood, which was less than that of the bell and some of the other attachments on the top of the engine.

A remote control unit was located in the engine cab of each locomotive, together with a loudspeaker and handset. An auxiliary control unit, with loudspeaker and handset, was mounted in a Pullman coach. By means of the auxiliary control unit, observers[1] were able to listen to all two-way communications; it also permitted establishment of two-way contacts between the train and fixed stations, and between trains. An interphone switch, of momentary-contact type, provided an a-f voice-communications link of intra-train type between the Pullman coach and the steam locomotive. In normal railroad service, however, this interphone circuit would be utilized principally for communications between personnel on footboards of the tender or at the front of the locomotive, and the engineman in the cab, as well as in two-way radio communications between these external control points and the fixed stations.

Results of Tests

The effectiveness of the satellite system in providing a strong, flutter-free signal at all points of the DT&I and Ford service areas in the Detroit industrial district was demonstrated on many occasions during the tests.

In one typical test, direct two-way space-radio communications was initiated between the Pullman coach, while in the Dearborn area, and the Flat Rock station, 13 to 14 miles distant. Although in most contacts a solid signal was received in the coach, *flutter* or local *dead spots* were observed in a few locations. When the satellite station at the Fordson yard was brought into operation from Flat Rock, the signal strength increased and solid two-way communication was established, with no trace of flutter or other discernible radio-frequency signal variation. As the train proceeded from Dearborn to Flat Rock, solid two-way communication was maintained. While the train was within the primary service area of the Fordson station, communication was maintained with this point, or with the Flat Rock station, as desired. When the train moved out of the primary service area of the Fordson station into the zone where the signals from the Flat Rock transmitter took control of the receiver, communications were maintained through the Flat Rock station.

It was noted that no heterodyne whistles were heard in the intermediate zone between the Fordson and Flat Rock stations. For a short distance, where the signals from the two fixed stations were approximately of the same strength, observers noted that signals from the Flat Rock and Fordson station, when transmitted during the same period, alternately predominated in the receiver on the train. This condition existed for an estimated distance of 3,000′ to 4,000′ in the intermediate zone. At all other points one station or the other took complete control, with no trace of the weaker signal being audible. When the fixed stations were modulated by one voice signal, as in satellite operation in which voice signals from Flat Rock were transmitted simultaneously from both transmitters via the induction link, the radio signals were received on the train from whichever station held control of the train receiver at any given period.

The value of the satellite system was particularly apparent in the Ford plant area, where tall steel-frame buildings and steel overhead construction adjoin the tracks of the Ford railroad system. In one test location, under a large steel-reinforced viaduct, directly-propagated v-h-f signals from the Flat Rock station could not be received. When the satellite station was actuated from Flat Rock, a clear high-level signal was provided. Similar results were obtained in other localized shielded areas where r-f signal levels of relatively low order were observed during

[1]Over 150 rail executives and communications engineers from major U. S. railroads were present during the tests.

direct space-radio transmissions from the Flat Rock station.

In addition to the tests of satellite operation, a number of test runs were conducted to determine the approximate distances over which effective two-way space-radio communications could be maintained in point-to-train and train-to-train service. In one preliminary test, solid two-way communication was maintained between the Flat Rock station and the steam locomotive on tracks of the DT&I railroad, in flat, open country, for a distance of 29 miles; with the squelch circuit held open, communications were maintained up to 34½ miles. In other tests, the steam locomotive and Pullman coach were moved into a large steel-frame locomotive maintenance building, with steel roof, in the center of the Ford plant. At this location, tall steel-frame buildings, cranes, and other metal structures intervened between the locomotive and the Flat Rock station, about 13 airline miles distant. In spite of these conditions, where a *dead spot* would normally be expected, solid two-way communications were maintained directly with Flat Rock, as readily as in open country. At this same location, two-way communications were also maintained with the Diesel locomotive which, at the time, was between large steel-frame buildings and beneath an overhead crane at the Murray Body Works in the Detroit Ecorse industrial district, about 3½ miles from the Ford plant. In open country, two-way communications between locomotives were established over distances of 7 to 8 miles.

System Advanages

As a result of the tests, it was generaly concluded that satellite operation, with induction-radio or other inter-station links, was entirely practicable in railroad operation, and that it afforded a degree of flexibility and utility not provided by single-station systems in which one fixed station, of relatively high power, is required to cover a large service area. In addtion, it was determined that the satellite system provides a desirable point-to-point radio communications link in event of line prostration, as in floods or heavy storms when pole lines may be destroyed for appreciable distances.

It was also apparent that at frequencies in the 152-162 mc band, an unusual degree of wave penetration is obtained in steel-frame buildings and in areas surrounded by tall steel-frame structures. These factors are expected to contribute to the over-all dependability and value of mobile communications services in industrial and urban areas.

PHASE to FREQUENCY MODULATION

(*Continued from page* 38)

modulator is to obtain a pair of sidebands with no carrier present. This may be accomplished by the circuit shown in Figure 5. In this circuit two tubes are excited in parallel by the oscillator signal. Audio modulation is applied in push pull so that tube *1* is increasing in amplitude, while tube *2* is decreasing in amplitude and vice versa. This means that if the current, i_1, in the plate circuit of tube *1* is

$$i_1 = I_o (1 + k_a \sin \Omega t) \sin \omega t$$

the current in the plate circuit of tube *2*, i_2, will be

$$i_2 = I_o (1 - k_a \sin \Omega t) \sin \omega t$$

The tubes should be balanced so that the values of I_o and k_a should be exactly alike in both of the tubes. The two currents are subtracted directly in the plate circuit, as shown in the diagram, where C_1 and C_2 are series tuning capacitors. The net effective current, i_o, is then given by

$$\begin{aligned} i_o &= 2 k_a I_o \sin \Omega t \sin \omega t \\ &= k_a I_o \cos (\omega - \Omega) t \\ &\quad + k_a I_o \cos (\omega + \Omega) t \qquad (18) \end{aligned}$$

showing that only the sidebands will be present in the output. The output wave form is shown in Figure 6. It will be noticed that the reversal in phase takes place when the amplitude of the signal goes through zero. The transformer coupling in the output of the balanced modulator, as shown in Figure 5, also serves as the 90° phase shift means. In any transformer the output voltage is equal to $-j \omega M$ times the current in the primary, where M is the mutual inductance, provided of course that it is the only coupling between primary and secondary. If the current in the plate circuit is in phase with the r-f oscillator signal then the output of the transformer will be at 90° to the oscillator voltage. As shown in Figure 3, the output of the transformer is now directly combined with the oscillator signal to yield the final f-m modulated signal.

Reviewing the complete process, we find that: (*1*)—input audio signal is distorted in a predetermined manner; (*2*)—amplitude modulation is applied on a balanced modulator to obtain the sidebands alone; (*3*)—phase of either the sidebands or the carrier is shifted in order that the resultants are 90° out of phase with one another; and (*4*)—the two resultant signals are combined to obtain an f-m signal that may be multiplied up to any deviation.

The question of shifting one signal 90° relative to another frequency is often confusing. Actually, by examining Figure 2 carefully, it can be seen that what is wanted is to delay both of the sidebands an amount equal to 90° of the carrier frequency. This is so close to a phase shift of 90° for each of the sidebands at their own frequency that this procedure is actually employed with no detrimental effect.

The Phasitron

The phasitron system affords a means for obtaining wide-angle phase modulation directly. If the audio voltage is predistorted, as stated in equation (*5*), the output of the phasitron will be a f-m signal. A schematic diagram of the phasitron tube is shown in Figure 7. Plates *1* and *2* are at a positive potential and draw electrons from the cathode. By means of the two focus electrodes these electrons are formed into a tapered thin edge disc. This disc, with the cathode for its axis, lies between the neutral plane and the deflector grid structure and extends out to plate *1*. The electrons in this disc are traveling outward from the cathode to the plates. They either land on the first plate or if they are lined up with any of the holes in plate *1* they will reach plate *2*. A three-phase constant frequency voltage is applied to the deflector grid, one phase to every third wire so that all the *A* wires in the figure would have one phase, all the *B* wires another phase, and all the *C* wires the third phase. At any instant, the electron disc will be distorted, as illustrated in Figure 8. This means that some electrons will travel slightly upward and others downward depending on their position in the disc. With an increase in time this disc will rotate, inasmuch as a three-phase voltage connected as described, for the grid, will progress uniformly around the cathode. Its rate will be the input frequency divided by one-third the number of grid elements, in this case one-twelfth the frequency.

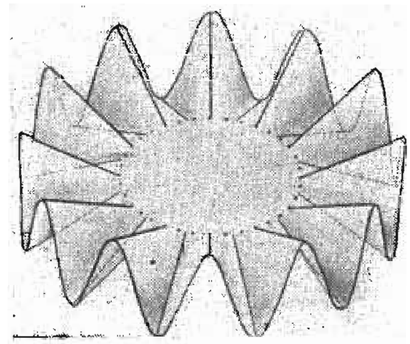


Figure 8
The distorted electron disc obtained when a three-phase voltage is connected to the deflector grid of the phasitron.

In Figure 9 appears a developed view of the holes in the first plate. The solid line shows how the elec-

(*Continued on page* 58)

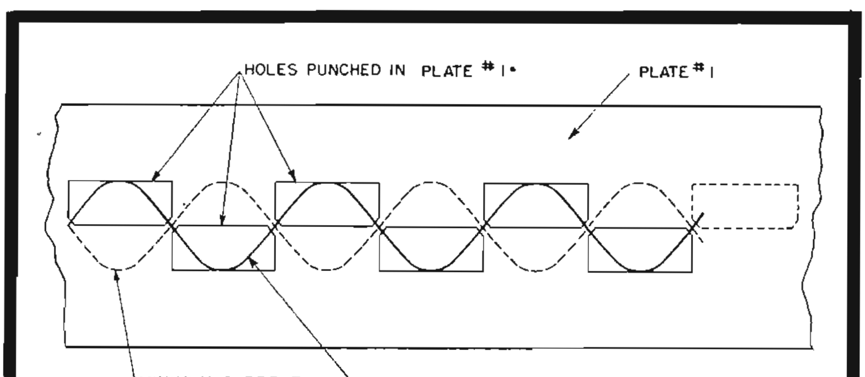


Figure 9
A developed view of the holes in the first plate showing how the edge of the electron disc either goes through the holes or intersects the first plate.

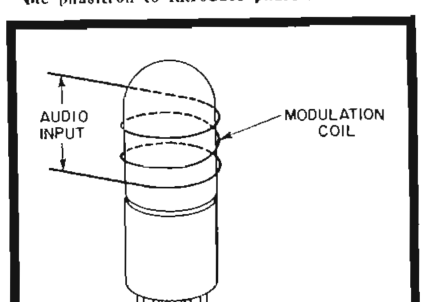


Figure 10
How the vertical magnetic field is impressed on the phasitron to introduce phase modulation.

FREQUENCY MODULATION

(*Continued from page* 56)

trons in the disc go right through the holes at one instant of time. The number of pairs of holes in the plate coincides with the number of cycles in the distorted electron disc, as shown in Figure 8, which in this case is twelve. As the disc rotates, less and less electrons will go through the holes until a half cycle later in the fundamental frequency time it will assume the dotted position shown in the figure, where no electrons will reach the second plate. In this manner, as the disc rotates, the current reaching the second plate will be sinusoidal in shape. The frequency of this current will normally be the frequency of the three-phase voltage introduced on the deflector grid.

Use of Magnetic Fields

Suppose now that we introduce a magnetic field perpendicular to the surface of the electron disc, as shown in Figure 10. Now the electrons traveling radially outward from the cathode will have a force exerted on them in a direction perpendicular to their path and perpendicular to the direction of the magnetic field. This will cause them to travel in a spiral about the cathode. As they travel in a spiral they will cause the edge of the disc to twist introducing a phase shift. In this manner phase modulation by the predistorted audio signal is introduced into the currents reaching the plates. Since the number of electrons reaching the plates does not change, no amplitude modulation should be present in the output. With this wide phase-angle modulation the amount of frequency modulation obtainable is quite large. A frequency deviation of ± 175 cps is obtainable at a frequency of 230 kc. This means that for a frequency deviation of 75 kc at the desired frequency a multiplication of 432 is necessary. The center frequency stability is determined by the constant-frequency voltage applied to the deflection grid. In the actual transmitter it is crystal generated.

References

N. Marchand, *Fundamental Relationships for F-M Systems*. COMMUNICATIONS; Jan. 1946.

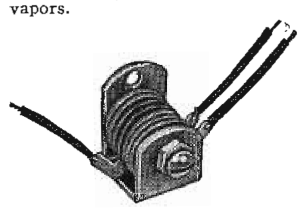
August Hund, *Frequency Modulation*, McGraw Hill Book Co.

THE INDUSTRY OFFERS . . .

BRADLEY LAB. RECTIFIERS

Copper oxide rectifiers, model CO12D4F, rated at either 6 volts a-c, 4½ volts d-c, or 35 milliamperes d-c have been announced by Bradley Laboratories, Inc., 82 Meadow St., New Haven 10, Conn.

The unit is said to be completely sealed, with a plastic compound, against moisture and corrosive vapors.



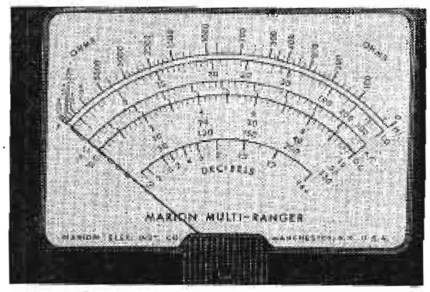
* * *

MARION MULTI-RANGER

A foundation instrument, the Multi-Ranger, designed to permit assembly of instruments for use as a voltmeter, milliammeter, high and low resistance ohmmeter, a-c voltmeter and decibel meter, has been announced by the Marion Electrical Instrument Company, Manchester, N. H.

Multi-rangers are available in 3½", 4½" and 8½" sizes. The basic sensitivity of the instrument is 400 microamperes and the internal resistance is 500 ohms, ± 1%. Alnico magnets are used.

The scale ranges, as normally supplied, include: 0-10-50-250 d-c volts, 0-10-50-250 a-c volts, 0-500 ohms and — 10 megohms, — 10 to + 14 db.



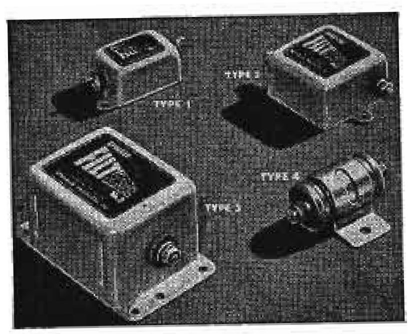
* * *

SPRAGUE INTERFERENCE FILTERS

Filterol radio interference filters have been announced by the Sprague Products Company, North Adams, Mass.

Designed for installation in series with the power line or interfering device. Basic circuit is a three terminal network of which the can is one terminal.

Four available types include 115 volts a-c or d-c ratings from 1 to 35 amperes, and one unit for 220 volts a-c or d-c is rated at 20 amperes.



* * *

KURMAN TWO AND THREE POLE RELAYS

Two and three pole relays, series 16, that are said to feature shockproof action under stress as high as ten times the force of gravity, have been developed by Kurman Electronics Corp., 35-18 37th Street, Long Island City 1, N. Y.

Activating armature is insulated from the

(*Continued on page* 60)

THE INDUSTRY OFFERS . . . —

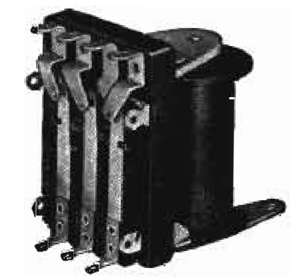
(*Continued from page 59*)

coutact arms by a bakelite link. This feature is said to reduce chatter and provides a dielectric strength of 1500 volts between all contacts and ground.

Rated for 2-watt operation. Contacts are rated to carry 2 amperes at 100 watts.

Coils may be selected for any d-c voltages between .5 and 150; any a-c voltage between 3 and 500.

Approximate dimensions are 2" long x 1 5/16" wide by 1¾" high. Weight is approximately 4 ounces.

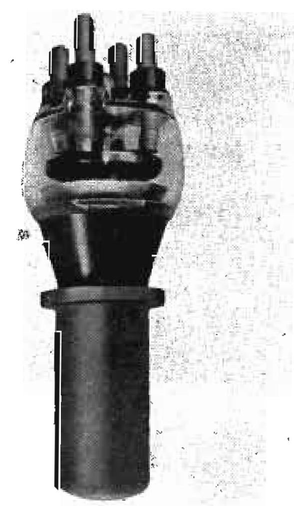


* * *

MACHLETT H-F TRIODES

An 889-A high-frequency, water cooled triode has been announced by Machlett Laboratories, Inc., Springdale, Connecticut. Tube features the use of Kovar for the glass seals

Grid and filament structures are mounted on one piece copper supports. Grid and filament contacts are gold plated externally.

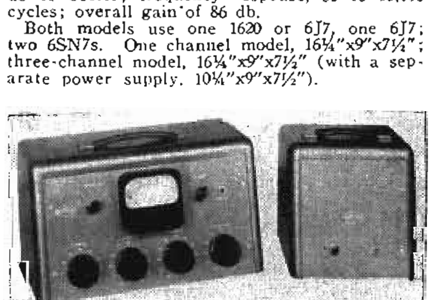


* * *

RAYTHEON REMOTE AMPLIFIERS

A one and three-channel remote amplifier has been announced by the Raytheon Manufacturing Company. Distortion is said to be less than 1½% from 50 to 200 cycles and less than 1% from 200 to 15,000 cycles; noise level of 60 db or better; frequency response, 30 to 15,000 cycles; overall gain of 86 db.

Both models use one 1620 or 6J7, one 6J7; two 6SN7s. One channel model, 16¼"x9"x7½"; three-channel model, 16¼"x9"x7½" (with a separate power supply, 10¼"x9"x7½").

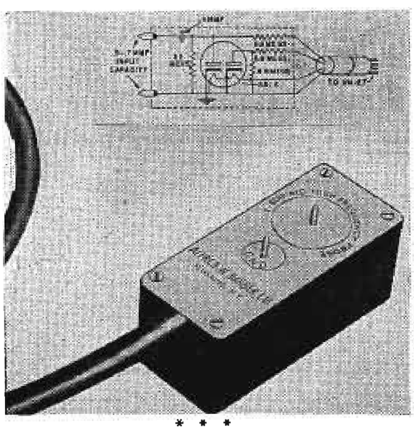


* * *

BARBER HIGH-FREQUENCY PROBE

A high-frequency probe, model 29, that is said to have an input capacity of ⅕ to 1 mmfd, has been announced by Alfred W. Barber Laboratories, 34-14 Francis Lewis Blvd., Flushing, N. Y. Frequency range, 0.5 to 500 megacycles.

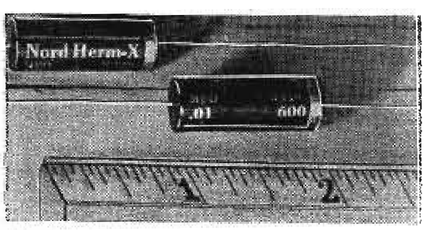
No multiplier is said to be reqnired to measure voltages up to 1000 volts.



* * *

NORD MOLDED TUBULAR CAPACITORS

Molded tubular capacitors, in capacities from 0.001 to 0.1 mfd and up to 1000 volts d-c working, have been develope: by Nor: Manufacturing Co., Inc., Bridgeport, Conn.

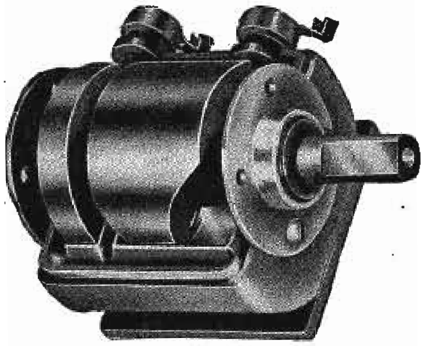


* * *

CAM-ROTOR CAPACITOR

A cam-rotor capacitor using solid barrel-cam rotors mounted on a low-loss plastic shaft, and a synthetic fluid dielectric, has been announced by the Timing Instrument Company, 106 Spring Street, New York 12, N. Y.

Features the sealed-in construction to prevent seepage of the dielectric fluid.



* * *

SIMPSON A-M/F-M SIGNAL GENERATOR

A signal-generator, model 415, for a-m and f-m, has been developed by the Simpson Electric Company, Chicago.

Control of r-f output through entire range. R-f output voltage is also said to be practically constant throughout the entire frequency range.

Modulation from 0 to 100% using either 400-cycle internal sine wave or an external source; high fidelity modulation up to 100% from below 60 cps to over 10 kc.

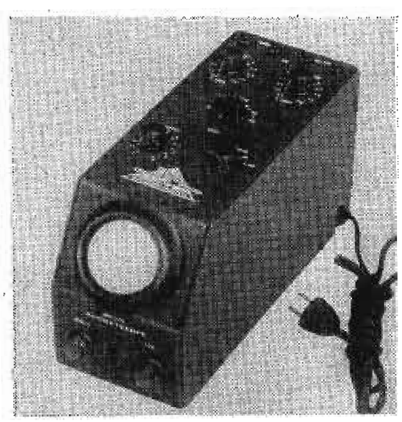
* * *

WATERMAN MINIATURE OSCILLOGRAPH

A 6⅛"x3¾"x10" oscillograph, weighing 5½ pounds, has been announced by Waterman Products Company, Inc., Philadelphia.

Known as model S-10-A, the unit incorporates a cathode-ray tube, vertical and horizontal amplifiers, linear time base oscillator, synchronization means and self-contained power supply.

The time base oscillator uses a double triode, connected as a multi-vibrator, that is said to produce a substantial linear trace from 10 cycles to 50 kc.



* * *

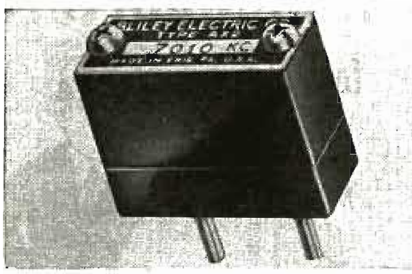
BLILEY PLATED CRYSTALS

A plated crystal for amateur frequencies, type

(*Continued on page 62*)

AX2, has been announced by the Bliley Electric Company, Erie, Pennsylvania.

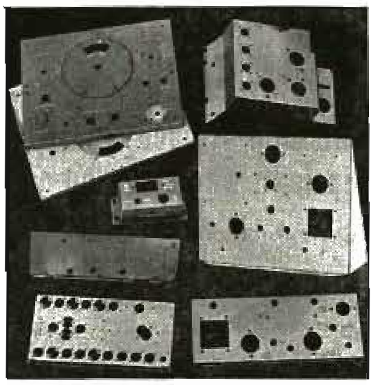
Features primary electrodes consisting of a micro-thin metal film deposited directly on the major crystal surfaces by evaporation under high vacuum. Secondary electrodes, under spring pressure, clamp the crystal and provide necessary thermal dissipation.



* * *

STAMFORD METAL HOUSINGS AND STAMPINGS

Stampings, housings and sub-assemblies of aluminum, brass, stainless steel, phosphor-



THE INDUSTRY OFFERS . . . —

(*Continued from page* 61)

bronze, etc., are now available from Stamford Metal Specialty Co., 427-29 West Broadway, New York 12, N. Y.

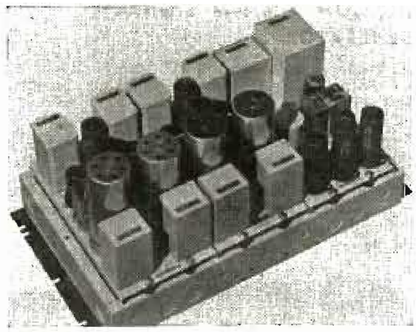
Tool and die-making, engraving, etching, spot welding, arc and gas welding, as well as the final assembly services are also available at Stamford.

* * *

LANGEVIN DUAL-CHANNEL AMPLIFIER

A dual-channel, fixed medium gain pre-amplifier, type 111-A, has been announced by the Langevin Company, Inc., 37 West 65th Street, New York 23, N. Y.

Each channel operates from a source impedance of 30, 250 or 600 ohms into a load impedance of 600 ohms. The output power is 0.038 watt (± 16 vu), with less than 1% total rss harmonic distortion at 400 cycles single frequency. Production run characteristics, ± 0.5 to 1 db over the range of 30/15,000 cycles.



* * *

ANDREW COAXIAL CABLE AUTOMATIC DEHYDRATOR

An automatic dehydrator, type 1800, for coaxial cables, that is said to be self reactivating, has been developed by the Andrew Company, 363 E. 75th Street, Chicago 19, Ill.

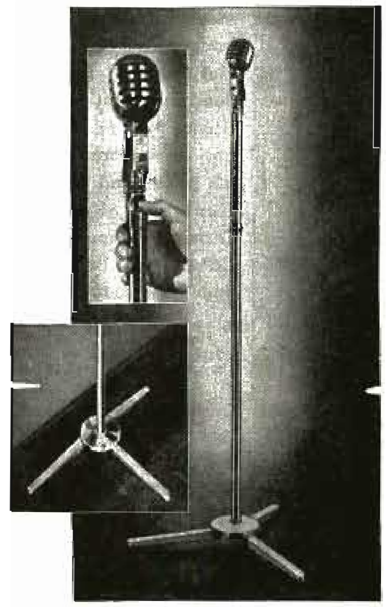
The unit consists of a motor driver air compressor which feeds one of the two cylinders containing a chemical drying agent. The air gives up all its moisture to the drying agent, entering the coaxial cable clean and dry.

* * *

ELECTRO-VOICE MICROPHONE FLOOR STAND

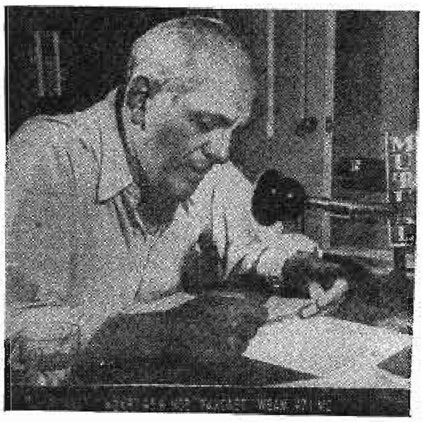
A microphone stand, the E-V floor stand, model 425, that raises, lowers, and locks with one-hand operation, has been announced by Electro-Voice, Inc., 1239 South Bend Ave., South Bend 24, Indiana.

Has a 3-legged, high-pressure, die-cast base. Height adjustment, 37" to 66"; three-leg spread, 17". Net weight, 7½ pounds.



HOGAN FAXIMILE SYSTEM

Above, John V. L. Hogan and the monitor recorder of his new faximile system, which provides 4,000 words of printed text or four pages of maps, diagrams or photographs in any combination of four 9½" x 12" sheets in fifteen minutes. Transmission is at rate of 100 lines per inch. Frequency of picture signal varies from 7,000 to 13,000 cycles, permitting the use of f-m stations for transmission. Paper is wet, electro-chemically processed, dried by special heating units when it appears on the viewing scanner. Home recorders are loaded with 400 linear feet of paper providing enough paper for 24 continuous hours of reception. Receiving process is mechanical, with electrical contact to the paper being made by a printer blade and a wire helix mounted on a drum which rotates at a 360 rpm rate. . . . Below, faximiled photograph reproduced at a receiving point 10 miles from transmitter.



IMPEDANCE CHART

(*Continued from page* 44)

tive or capacitive, then both the magnitude and phase of the input impedance will depend on the termination.

Example

The chart merely summarizes these calculations and gives a ready reference for the various conditions. For example, a three-quarter wavelength line with a zero-impedance termination appears as an open circuit at the sending end. If the termination is a capacitance whose magnitude is less than Z_0, the input appears as an inductive reactance whose magnitude is greater than Z_0.

In June COMMUNICATIONS . . .
Preventive Maintenance for Broadcast Stations—F-M Transmitters Using Phase Modulation—Tuned Circuits for V-HF and S-HF.

ADVERTISERS IN THIS ISSUE

COMMUNICATIONS—MAY, 1946

for Measuring Complex Waveforms

THIS analyzer offers the simplest, most accurate and most direct method of measuring the amplitude and frequency of the components of any complex electrical waveform.

It is ideally suited to hundreds of harmonic-distortion measurements on such equipment as any type of audio apparatus; broadcast receivers and transmitters; telephone and public address systems, oscillators, amplifiers and other vacuum-tube circuits; hum measurements in a-c operated communication equipment; harmonic studies of electric power systems and electric machinery; induction studies on telephone lines.

In its essentials this analyzer consists of a heterodyne-type vacuum-tube voltmeter with a highly selective filter using three quartz crystals. At only 60 cycles from resonance the attenuation is down by 75 decibels, yet tuning is very easy by virtue of the 4-cycle flat top characteristic at resonance. Standards for both voltage and frequency are built into the analyzer and can be used to check its calibration at any time.

The frequency range is 20 to 16,000 cycles and the voltage range 300 microvolts to 300 volts full scale. The instrument is completely a-c operated and has no pickup from external magnetic fields.

TYPE 736-A WAVE ANALYZER $720.00

WRITE FOR COMPLETE DATA

GENERAL RADIO COMPANY

Cambridge 39, Massachusetts

90 West St., New York 6 | 920 S. Michigan Ave., Chicago 5 | 1000 N. Seward St., Los Angeles 38

Electro-Voice ANNOUNCES THE CARDAX

A NEW Cardioid Crystal Microphone

with Revolutionary New MECHANOPHASE* Principle of Unidirectivity . . . Dual Frequency Response . . . High Output . . . and other big features!

EXCLUSIVE NEW MECHANOPHASE* PRINCIPLE DEVELOPED BY Electro-Voice

Utilizes a phase shifting diaphragm to produce a high degree of unidirectivity at all frequencies. Gives true cardioid characteristic by nullifying back pick-up. Unlike any previous method of obtaining unidirectivity and has many important advantages.

*Patents Pending

Here, for the first time, you get *all* these features in *one* microphone! With amazing flexibility, new CARDAX efficiently serves many applications . . . easily solves everyday problems of sound pick-up and reproduction!

★ **TRUE CARDIOID POLAR PATTERN** New E-V Mechanophase* principle gives wide-angle front pick-up in true cardioid pattern over wide frequency range. Sound at rear *dead* zone cancels out and is not reproduced.

★ **STOPS FEEDBACK—CUTS BACKGROUND NOISE AND REVERBERATION PICK-UP** Permits nearly double usable loud speaker volume. Simplifies microphone and speaker placement. Assures finer reproduction of just the sound wanted.

★ **DUAL FREQUENCY RESPONSE** Screw control on back gives (a) Wide range flat response for high fidelity sound pick-up or (b) Wide range with rising characteristic for extra crispness of speech or high frequency emphasis.

★ **HIGH OUTPUT LEVEL** —57 db for flat frequency response. —48 db for rising frequency response.

★ **VOICE AND MUSIC PICK-UP EXACTLY AS DESIRED** Ideal for public address, recording, remote broadcast, communications . . . indoors and outdoors.

★ **FULLY EQUIPPED FOR CONVENIENT OPERATION** Tilting bead. Built-in "On-Off" switch. Dual frequency range selector switch. Cable connector. 20 ft. cable. Bimorph crystal. 5/8"-27 thread. New modern functional design. Satin chrome finish. **CARDAX Model 950, List Price........$37.00**

Licensed under Brush Patents. Electro-Voice Patents Pending.

SEND FOR BULLETIN NOW
Get full facts about amazing new CARDAX! Describes Mechanophase. Shows how dual frequency response selector works. Includes diagrams and response curves.

No Finer Choice Than **Electro-Voice MICROPHONES**

ELECTRO-VOICE, INC., 1239 South Bend Ave., South Bend 24, Indiana
Export Division: 13 East 40th St., New York 16, N. Y., U.S.A.—Cables: Arlab