'53-1

Communication Engineering

Jan.-Feb. 1953 MILTON B. SLEEPER, Publisher Price 65 Cents

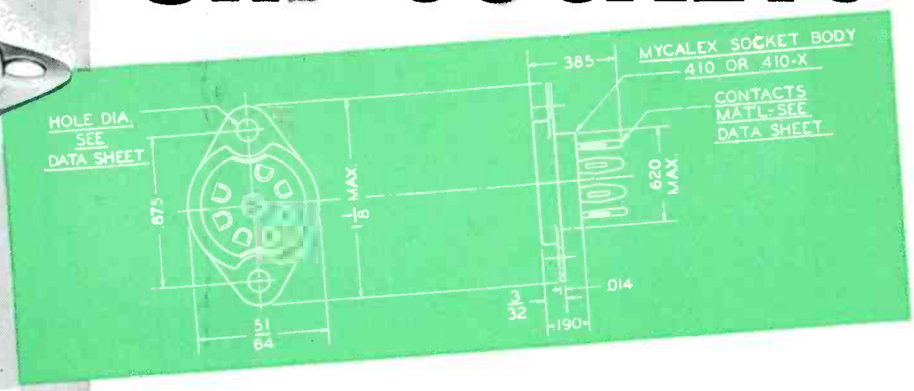
Established as FM 1940

THE complete answer TO uhf SOCKET PROBLEMS—

"MYCALEX 410"

7- AND 9-PIN

UHF SOCKETS



MYCALEX engineers designed these sockets to provide a complete, yet economical, solution to UHF tube mounting problems. Exhaustive tests have proven their mechanical excellence and high electrical efficiency. The use of "MYCALEX 410" (injection molded glass-bonded mica) with its great dimensional stability permits a minimum amount of dielectric to be used in the body structure. This plus other unique design features results in extremely low inter-electrode capacitance. In addition to its other advantages—high arc resistance, high dielectric strength, non-porosity, etc., "MYCALEX 410" has very low dielectric loss at all frequencies including UHF and thereby offers great advantage over phenolic materials. "MYCALEX 410" operates continuously in temperatures up to 650°F with practically no change in electrical properties or mechanical structure. Soldering operations will not cause body distortion.

MYCALEX TUBE SOCKET CORPORATION

Under exclusive License of Mycalex Corporation of America • 30 ROCKEFELLER PLAZA, N. Y. 20

... ELECTRICALLY EFFICIENT!

... MECHANICALLY PERFECT!

- LOW INTER-ELECTRODE CAPACITANCE
- VERY LOW DIELECTRIC LOSS
- HIGH DIELECTRIC STRENGTH
- PERMANENT DIMENSIONAL STABILITY
- NON-HYGROSCOPIC, NON-WARPING

TROUBLE-FREE CONTACT TERMINALS!

Contact terminals on these sockets are so designed that the effective inductance from soldered connection to the tube base is no greater than if the connection was made directly to the tube pin. Special design results in high contact area pressure that effectively reduces contact resistance. Contact terminals are secured in the body in a manner that permits 90° bending of the tab without weakening.

INFORMATIVE DATA SHEETS AVAILABLE!

Write for your complete set, together with loose-leaf binder for instant, easy reference. Your request will automatically assure prompt forwarding of all subsequent Mycalex data sheets and catalog material. Write on company letterhead please.

ALL TYPES OF MOUNTING HARDWARE!

"MYCALEX 410" UHF Sockets, 7 or 9 pin, can be furnished mounted in various standard saddle hardware—regular saddles (top or bottom mounted), saddles with ground lugs, snap or JAN types, permitting the use of radio tube shields.

SINCE 1919 MYCALEX THE INSULATOR TRADE MARK REG US PAT OFF

MYCALEX CORPORATION OF AMERICA

Owners of 'MYCALEX' Patents and Trade-Marks

Executive Offices: 30 ROCKEFELLER PLAZA, NEW YORK 20 • Plant & General Offices: CLIFTON, N. J.

Communication Engineering

Formerly FM-TV and RADIO COMMUNICATION

VOL. 13 JANUARY - FEBRUARY, 1953 NO. 1

COMMUNICATION REVIEW

RESEARCH & DEVELOPMENT

MANUFACTURING & DESIGN

SYSTEMS ENGINEERING

MICROWAVES

SPECIAL DEPARTMENTS

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CPA AUDIT

CIRCULATION AUDITED BY HENRY R. SYKES CERTIFIED PUBLIC ACCOUNTANT SYKES, GIDDINGS & JOHNSON PITTSFIELD, MASSACHUSETTS

SYSTEMS DATA

THE table presented here, covering applications filed with the FCC for Safety and Special Services during the third quarter of 1952, is the most complete picture that has been compiled to show the direction of growth of two-way radio telephone communication. It not only lists the applications for mobile and base transmitters, but breaks them down into equipment for 30 to 50 and 152 to 174 mc., in order to reveal the relative activity in these bands. In addition, the table includes the listing of hand-carried transmitter-receiver units, originally developed for the low-power industrial service, but coming into increased use in other services.

In the tabulations for the first and second quarters of 1952, published previously, mobile and base transmitters were not broken down by frequency bands, so that the recapitulation can only be shown in this way:

	MOBILE	BASE
1st Quarter	8,313	1,221
2nd Quarter	9,883	1,469
3rd Quarter	8,322	1,032
	26,518	3,722

It should be noted that the number of mobile units purchased and put into service is actually less than the figures shown here because the FCC now recommends that applicants apply for the number of units they *expect* to use. Purpose of this is to eliminate clerical and processing work on additional applications each time a licensee purchases additional mobile transmitters. The number of fixed transmitters is exact.

TABLE OF APPLICATIONS FILED IN THE THIRD QUARTER, 1952

				30 to 50 mc.			152 to 174 mc.		
	MOBILE	BASE	PORT.	MOBILE	BASE	PORT.	MOBILE	BASE	PORT.
Police	815	111	36	356	60	18	459	51	18
Fire	590	61	31	301	16	19	289	45	12
Special Emergency	1,168	97	—	1,164	88	—	4	9	—
Highway Maintenance	60	9	—	60	9	—	—	—	—
Forestry Conservation	241	49	20	21	33	—	220	16	20
Power Utility	605	138	81	289	85	26	316	53	55
Pipeline Petroleum	313	109	7	264	84	—	49	25	—
Special Industrial	1,615	185	90	1,153	74	46	462	111	44
Low-Power Industrial	—	—	372	—	—	93	—	—	279
Relay Press	60	2	—	—	—	—	60	2	—
Motion Picture	52	—	10	—	—	10	52	—	—
Forest Products	462	28	4	305	17	4	121	11	—
Taxicabs	1,183	119	—	—	—	—	1,183	119	—
Railroads	69	52	13	—	—	—	69	52	13
Highway Trucks	477	35	477	35	—	—	—	—	—
Intercity Buses	—	—	—	—	—	—	—	—	—
Transit Utilities	30	2	—	30	2	—	—	—	—
Automobile Emergency	94	25	—	94	25	—	—	—	—
Radio Paging	—	23	—	—	23	—	—	—	—
Common Carrier	275	6	—	200	2	—	75	4	—
Miscellaneous Com. Carrier	253	4	—	—	—	—	253	4	—
	8,322	1,032	664	4,714	530	223	3,612	502	441

Relay, control, and point-to-point transmitters are not represented, but they are enumerated in the text below, together with other notes on individual services.

In the table, services are grouped as Public Safety, Industrial, Transportation, and Common Carrier systems, in accordance with FCC practice:

Other services such as aircraft, airdrome, civil air patrol, coastal, and radio location, are listed in COMMUNICATION ENGINEERING Weekly Reports but are not included here because of their special nature.

In addition to the transmitters listed above, applications were filed for the following relay or control transmitters: POLICE 2 on 72 mc., 8 on 150 mc., 3 on 950 mc., 9 Speedmeters. FIRE 4 on 150 mc., FORESTRY 10 on 72 mc., 13 on 150 mc., 3 mobile relays on 150 mc. POWER UTILITIES 1 mobile relay on 48 mc., 14 on 72 mc., 1 on 150 mc., 5 mobile and 26 base on 450 mc., 4 on 950 mc., PIPELINE 10 on 72 mc., 1 mobile relay on 150 mc., 600 mobile and 44 base on 450 mc., 58 on 1865 mc., 18 on 6625 mc. FOREST PRODUCTS 9 on 72 mc. SPECIAL INDUSTRIAL 6 on 72 mc., 1 mobile relay on 150 mc. AUTO EMERGENCY 120 mobile and 3 base on 450 mc.

Now you, too, can own the best...

BENDIX REVOLUTIONARY 2-WAY RADIO!

It's new, it's clean, it's rugged. And it works just as good as it looks. Here is 2-way radio that's been tested under the most difficult conditions . . . and it comes up every time with miles ahead communication. It gives you dozens of advantages over ordinary mobile radio . . . but doesn't pull any more amps than a headlight.

Gets the signal . . . not the noise

A newly perfected electronic squelch is the secret of clear as home radio tone. It has a delayed action that gives you all the signal . . . none of the noise.

Easier to service, maintain

Your Bendix is easier to service and maintain. (Bendix, for instance, uses Selenium stacks instead of rectifier tubes. They never wear out). Your Bendix is completely accessible for service or adjustment. The transmitter, receiver and power supply are all in one housing . . . separate chassis for easy 3-way removal . . . pivot, straight up, or straight out.

From hand sets to land stations

In addition to the latest type of mobile equipment . . . Bendix offers a complete line of fixed stations from 2½ to 250 watts.

As well as accessories from handsets to speakers, antenna to shock mounts . . . plus all technical help in obtaining license and complete system engineering.

Write today . . . because you too can now afford the best in 2-way radio. Bendix costs you no more than ordinary equipment. Get all the information.

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BUY ON INSTALLMENT PLAN

Bendix has developed with local banks, what has been called one of the finest financial plans anywhere. You pay for your new Bendix 2-way radio . . . as you use it and as it makes money for you. Write for details.

PRODUCT INFORMATION

Resonance-Grid Dip Meter: Portable combination instrument serves as a resonance-grid dip meter, 2.4 to 205 mc., and as impedance-inductance meter, 50 to 500 ohms and .01 to 100 microhenries; has RF probe with self-contained DC amplifier for shielded-circuit work, and a crystal oscillator for marker generation. Weight, 14 lbs. with batteries. Premier Mfg. Company, 943 N. Russell Street, Portland 12, Oregon.

UHF Signal Generator: New 300 to 1000-mc. signal generator has output from .1 microvolt to 1 volt, continuously variable; 400-cycle internal modulation at 0 to 30%, or 50 to 20,000-cycle external modulation. Output impedance is 50 ohms, and VSWR is 1.3 to 1 or better. Useful for direct gain measurements on RF amplifiers, testing UHF communication or TV receivers, slotted-line work, and filter, antenna, and matching network tests. Measurements Corporation, Boonton, N. J.

JAN Octal Sockets: Octal tube sockets meeting specifications JAN-S-28A are now available with ceramic or phenolic plastic bases. Mounting saddles are nickel-plated brass with 4 hot-tinned ground lugs. Contacts are silver-plated phosphor bronze or beryllium copper, hot-tin dipped. Sylvania Electric Products, Inc., 1740 Broadway, New York 19.

Coaxial Accessories: To integrate type 874 coaxial line equipment with other systems, the following units have been made available: 1) adaptors for interconnection with other equipment. 2) a constant-impedance line-stretcher (adjustable line). 3) component mount for measurement of circuit elements, 4) a balun, 5) short and open circuit terminations, and 6) an insertion unit for mounting arbitrary coaxial networks. General Radio Company, 275 Massachusetts Ave., Cambridge 39, Mass.

Ruggedized Meters: Two types of ruggedized indicating instruments have been added to the Phaostron line. One is a hermetically sealed movement for AC or DC meters used under severe conditions of shock, vibration, or weather exposure; made in standard 1½, 2½, 3½, and 4½-inch sizes. Also available are laboratory-type AC and DC voltmeters and DC milliammeters, singly or in sets of 4. Each has 5 ranges, and scales which change according to the range selected. The Phaostron Company, South Pasadena, Calif.

Decade Inductors: Covering the range from 1 millihenry to 10 henries in 4 individual decade units or 1 combination unit, with special ranges available on request, a new laboratory line of inductors is guaranteed to be accurate within 1%. Each toroidal decade unit has complete electrostatic shielding. Bulletin on request. Lenkurt Electric Company, San Carlos, Calif.

Mycalex Applications: Two new coil forms with metal inserts have been developed for special applications requiring high dimensional stability, close tolerances, high temperature capabilities, and high-altitude performance, using Mycalex 410 insulation. Also, an RF tuner plate for precision tuning of 5 HF channels under heavy moisture conditions incorporates silver contacts, steel distributing rings, and an integral center hub, made by injection molding process. Mycalex Corp. of America, Clifton Boulevard, Clifton, N. J.

2-Band Mobile Receiver: Low-cost monitor communications receiver, model DR-200, operates on crystal-controlled fixed frequencies in both 30 to 50 and 152 to 174-mc. bands or is continuously tunable, as determined by switch. Thus, rapid instantaneous switching between two channels is available, while retaining full band coverage. Radio Apparatus Corp., 55 N. New Jersey Street, Indianapolis, Indiana.

VHF-UHF Capacitor: Variable capacitor for 50 to 500-mc. operation incorporates two sections in series, with rotor completely insulated by glass ball bearings. Because no contacts are made to rotor, contact and bearing noise is elimated. Hammarlund Mfg. Company, Inc., 460 W. 34th Street, New York 1, N. Y.

High-Level Microphone: Hand-held noise-cancelling model 208 mobile microphone has 100 to 4,000-cycle response, output level of —50 db; is blast and water-proof, shock-resistant. Articulation is 97% in quiet surroundings, 88% with 115 db ambient noise. Weight, 3 oz. Electro-Voice, Inc., Buchanan, Michigan.

Microwave Equipment: New 2,000 mc. equipment employs same basic units for terminal and repeater stations. Accompanying frequency-division multiplex equipment provides 30 voice channels, or telegraph channels at 15 per voice channel. Accessories are available for complete point-to-point systems. Westinghouse Electric Corp., P. O. Box 2099, Pittsburgh 30, Pa.

High-Gain Base Antennas: New method of co-linear stacking and feed results in high-gain wide-band base-station antennas. Standard 3 and 7-element antennas are in production for 160 and 450-mc. bands, provide gains of 4 and 7.2 db respectively, with special-purpose antennas made to order. Units will withstand 100-mph. winds with ½-inch ice coating. Mark Products Company, 3547-49 Montrose Avenue, Chicago 18, Ill.

Service Instruments: Two new instruments for communication maintenance applications have been made available. A portable frequency and deviation meter, type CX-8A, can be used for checking 1 or 2 specified frequencies in the 25 to 50 or 152 to 174-mc. band to an accuracy of ±.002%, deviation to an accuracy of ±200 cycles, and relative field strength. Can be used also as a signal source for alignment. Weight is 10 lbs.

A general-purpose test meter is available also for measurement of voltage, current,

Concluded on page 11

...has everything you need for PRINTED CIRCUITS

First to provide Tubes and Transistors that are correctly designed for quick, efficient printed circuit assembly. For the ultimate in portable performance, combine Raytheon's high-efficiency, filamentary Subminiature Tubes with Raytheon's Junction Transistors.

Subminiatures	Filament Volts	Filament Ma.	Plate Volts	Screen Volts	Grid Volts	Plate Ma.	Screen Ma.	Mutual Cond. Umhos.	Voltage Gain	Plate Resis. Meg.
1AG4 Output Pentode	1.25	40	41.4	41.4	-3.6	2.4	0.6	1000	35†	0.18
1AH4 RF Pentode	1.25	40	45.	45.	0	0.75	0.2	750		1.5
1AJ5 Diode-Pentode	1.25	40	45.	45.	0	1.0	0.3	425	50	0.3
1V6* Mixer-Pentode	1.25	40	45.	45.	0	0.4	0.15	200**		1.0
1V6* Osc.-Triode			45.	—	Rg = 1 meg.	0.4	—	550		
1AK4 RF Pentode	1.25	20	45.	45.	0	0.75	0.2	750		1.5
1AK5 Diode-Pentode	1.25	20	45.	45.	5 meg.	0.5	0.2	280	40	0.4

†Power Output — milliwatts **Conversion Conductance

***Type 1V6 is a high performance, low battery drain converter. Note the comparison with 1R5 using 45 volt supply.**

	1V6	1R5
Total Cathode Current (ua)	960	2750
Conversion Conductance (umhos)	200	235
Plate Resistance (megohms)	1.0	0.6
Conversion Gain (load = 175K)	30	32
Equiv. Noise Resistance (ohms)	70K	180K

PNP JUNCTION TRANSISTORS
(Average Characteristics at 30° C)

	CK721	CK722
Collector Voltage (volts)	-1.5	-1.5
Collector Current (ma.)	-0.5	-0.5
Base Current* (ua.)	-6	-20
Current Amplification Factor*	40	12
Power Gain* (db)	38	30
Noise Factor* (1,000 cycles) (db)	22	22

*Grounded Emitter connection

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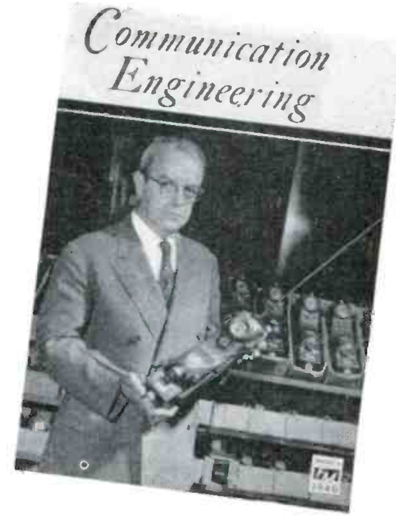
RAYTHEON MAKES ALL THESE:

RELIABLE SUBMINIATURE AND MINIATURE TUBES • GERMANIUM DIODES AND TRANSISTORS • NUCLEONIC TUBES • MICROWAVE TUBES • RECEIVING AND PICTURE TUBES

THE COVER PICTURE

Most old-timers who remember the Acme Apparatus Company know George Bertram, whose picture appears on the cover of this issue. But few realize that it was he who put together and is now directing the organization responsible for one of the Signal Corps' most useful pieces of communication equipment, the PRC-6. As assistant vice president and manager of Raytheon's special products division, George Bertram presides over a separate plant devoted to PRC-6 production. It was there that the photographs were taken for the article describing the design of this remarkable unit, and some of the production methods.



COMPANIES & PEOPLE

Capt. Henry J. Round:

Awarded the Armstrong medal by the Radio Club of America at the annual banquet in New York, December 12. Shortly after joining Marconi's Wireless Telegraph Company, Ltd. in England, he came to America to operate BA, the first commercial wireless station in this country. BA, at Babylon, Long Island, was owned by the American Marconi Company. Returning to England in 1907, he assisted Marconi in experiments between Clifden and Glace Bay, the first transoceanic circuit. Capt. Round's greatest achievement came during World War I, when he developed extremely accurate position-finding equipment, and greatly improved means for amplifying weak signals. This work had an immediate and profound effect on the outcome of the War.

Licensed Operators:

Demand for licensed operators continues to grow faster than the supply, and the situation is becoming serious despite the increase in number of companies handling maintenance of communication systems on contract.

To assist in providing licensed operators for new systems, Cleveland Institute of Radio Electronics is cooperating with equipment manufacturers in a plan to prepare men for FCC examinations. Those selected for training are generally employees of companies which own communication systems. Cost of training is low, and CIRE guarantees that trainees will pass license exams.

1,840-Mile Radio Relay:

Now in operation by the Transcontinental Gas Pipe Line Corporation from Falfurrias, Texas to Newark, N. J. There are 59 microwave stations along the route, handling up to 12 channels. Three spurs connect the main line with division offices at Baton Rouge, Atlanta, and Culpepper.

New Address:

Administrative and home offices of National Union Radio Corporation have been moved from 350 Scotland Road, Orange, N. J., to Jacksonville Road, Hatboro, Pa. Building at the former address is being given over entirely to research. New offices are adjacent to NU picture tube plant, 15 miles north of Philadelphia. Phone number is Hatboro 1791.

Dr. John Ruze:

Appointed director of research for Gabriel Laboratories at Needham Heights, Mass. Previously, Dr. Ruze was assistant chief of the antenna laboratory at the Air Force Cambridge Research Laboratories.

Form 400 Troubles:

We haven't heard anything directly about the effects of putting the FCC Form 400 into use, but from an outsider's impression of the impact of this change on the FCC staff, we gather that the members will not be distinguished much longer as blondes, brunettes, and red heads. Gray may become the standard color. As for the smoke coming out of Temporary T, it could be the furnace, or does that building have one? Our own view: we still stick to the opinion previously expressed that "Form 400 will defeat its intended purpose."

Rear Admiral Willis E. Cleaves:

Named general manager of Bendix Radio's communication division. Admiral

Continued on page 9

COMPANIES & PEOPLE

(Continued from page 8)

Cleaves, who joined Bendix recently as assistant to the general manager of that division, was formerly director of aviation sales at Collins Radio.

Radio Paging Systems:

As our Weekly Reports of new applications show, the number of companies which have filed for radio paging transmitters is going up steadily, but they aren't going on the air. Meanwhile, efforts of Royalcall Company of Cleveland are attracting attention, for engineer Al Gross is undertaking to operate a paging system on 460 mc.

Paul V. Pembricks:

Appointed assistant plant manager at Hammarlund Manufacturing Company with responsibility for all manufacturing operations. Prior to joining Hammarlund in 1951 as methods engineer, he was with Western Electric at Kearny for 14 years.

1953 IRE Convention:

Radio engineers from far and wide will be traveling to New York for the IRE Show and Convention at Grand Central Palace, March 23 to 26. You'll find Communication Engineering, TV & Radio Engineering, and High-Fidelity at booth 3-310, opposite the row of Audio Theatres. This, by the way, will probably be the last IRE Show at that address. A note from J. H. Ruiter, chairman of the exhibitors' sub-committee, advises that the Internal Revenue Department is going to take over Grand Central Palace this year, so that a new location must be found for the Show in 1954.

New Subsidiary:

A new corporation, Motorola Communications and Electronics, Inc., wholly owned by Motorola, Inc., has been formed to distribute the products manufactured by the communications and electronics division of the parent company. No change in personnel is involved.

Growth of Small Business:

Percentage-wise, employment in small businesses is growing faster than in large ones, according to the National Production Authority. Taking June 1950 as a base, employment in companies with 1 to 99 workers was up 27% on April 1952; companies with 100 to 499 workers, up 25%; those with 500 or more, up 14%. That is not a picture of numerical growth, however, nor does it indicate that small concerns whose activities are

Concluded on page 10

COMPANIES & PEOPLE

(Continued from page 9)

related to military production are making gains in the direction of stability or permanence. More realistic inference is that a large number of small companies will feel the first pinch when military contracts are cut back.

West Coast Company Purchased:

Acme Electronics, Inc. of Pasadena has been purchased by the Aerovox Corporation. Acme manufacturers filters, toroidal coils, delay lines, power supplies, and magnetic amplifiers. President Hugh P. Moore will continue to manage the two Pasadena plants.

Arthur L. Chapman:

Appointed to the newly-created post of vice president in charge of electronic operations for Sylvania. Mr. Chapman, who joined the company in 1933, has been a vice president for the past two years. He will now be responsible for the operation of Sylvania's radio and television, parts, electronics, radio tube, and picture tube divisions, with plants in 22 cities, spread over 9 states.

Communications Comeback:

Link Radio is again taking an active part in the 450-mc. field, and is producing equipment for this band in increasing quantities. Fred Link is devoting his full time to effecting a reorganization. Meanwhile, under the direction of Stuart Meyer as chief engineer, and Ray Chappelle as general manager, the regular line of Link fixed and mobile equipment has been revised to incorporate new electrical and mechanical design features.

Company Name Changed:

Emsco Derrick & Equipment Company, manufacturers of radio towers has now changed its name to Emsco Manufacturing Company.

Industrial Radio Systems:

Annual revision of the Registry of Industrial Systems has required so many additions and changes as to make it a tremendous task. This work, which we carry out at the FCC offices in Washington, calls for checking the file copy of each license, and comparing it with the last issue of that Registry to see if it was listed previously, or if any modification has been made. In the new edition, each added listing is identified with an asterisk. Services covered in the Industrial Registry are: power utilities, pipelines and petroleum, special industrial, low-power industrial, relay press, motion picture, and forest products.

PRODUCT INFORMATION

(Continued from page 6)

and relative ERP, and is designed specifically to simplify service and installation work on mobile equipments. Weight with batteries, 4 lbs. RCA Victor, Engineering Products Dept., Camden, N. J.

Selenium Rectifiers: Designed for railroad radio applications, a new line of selenium rectifiers is available in 13 cell sizes from 1 by 1 inch to 6 by 6 inches. Combinations for handling current from a few milliamperes to a thousand amperes can be obtained. Bogue Electric Mfg. Company, 52 Iowa Street, Paterson 3, N. J.

NEW LITERATURE

Hermetic Seals: An extremely wide range of glass-to-metal hermetic seals and header assemblies is listed in Catalog S-53, available from The Sealtron Company, 9701 Reading Road, Cincinnati 15, Ohio.

Junction Transistors: Data sheets are available on *p-n-p* junction transistor types CK721 and CK722, now commercially available. CK721, having a power gain of 38 db, is presently limited in quantity; CK722, with a power gain of 30 db, can be obtained in production quantities now. Raytheon Mfg. Co., Receiving Tube Div., Newton 58, Mass.

Variable Resistors: Complete military and civilian lines of variable resistors, with attached switches and concentric-shaft tandem arrangements, are described in bulletin No. 164 from Chicago Telephone Supply Corp., Elkhart, Indiana.

Capacitor Data: Information on foil-paper capacitors with tubular metal cases and vitreous-ceramic terminal end seals can be obtained by writing for the bulletin "Aerovox Miniature Metal-Cased Capacitors". Aerovox Corporation, New Bedford, Mass.

Clipper Diode-Rectifier: Application and operating information is available on the liquid-cooled clipper diode and rectifier type 6269, a miniature ruggedized version of the 3B29. Amperex Electronic Corp., Hicksville, Long Island, N. Y.

MEETINGS and EVENTS

FEBRUARY 5-7,
IRE SOUTHWESTERN CONFERENCE & SHOW
Plaza Hotel, San Antonio, Texas

MARCH 23-26,
IRE NATIONAL CONVENTION & SHOW
Grand Central Palace, New York City

APRIL 11,
NEW ENGLAND RADIO ENGINEERING MEETING
Univ. of Connecticut, Storrs, Conn.

APRIL 18,
CINCINNATI SECTION IRE CONFERENCE
Cincinnati, Ohio

APRIL 29 - 30, MAY 1,
ELECTRONICS COMPONENTS SYMPOSIUM
Shakespeare Club, Pasadena, Calif.

MAY 11-13,
IRE AIRBORNE ELECTRONICS CONFERENCE
Dayton, Ohio

MAY 18-21,
1953 ELECTRONICS PARTS SHOW
Conrad Hilton Hotel, Chicago

MAY 24 - 28,
45TH ANNUAL NAED CONVENTION
Conrad Hilton Hotel, Chicago

AUGUST 19 - 21,
WESTERN ELECTRONIC SHOW
San Francisco Auditorium, San Francisco

NEW . . .
CUSTOM DESIGNED FOR AIRCRAFT

Typical Operation

Radio Frequency Power Amplifier or Oscillator

Class-C telegraphy or FM telephony, 200-400 mc.

D-C Plate Voltage	1000 volts
D-C Screen Voltage	250 volts
D-C Grid Voltage	—110 volts
D-C Plate Current	160 ma
D-C Screen Current	6 ma
D-C Grid Current	8 ma
Driver Output Power	8 watts
Power Input	160 watts
Useful Power Output	100 watts

Eimac announces the development of the 4X150D radial-beam power tetrode designed for equipment simplification in commercial and military aircraft and vehicular operation. Through a specially constructed heater that has a rating of 26.5 volts at 0.57 amperes, Eimac presents aviation with a tube ideal for 24-28 volt electrical systems. Except for the heater the 4X150D is identical to the universally accepted 4X150A and can be used with the 4X150A air-system socket. The 4X150D is a natural for aircraft and mobile equipment because it combines high power output with small size and a ruggedness that gives it great immunity to damage by thermal or physical shock. Employed as an amplifier, oscillator or frequency multiplier into UHF regions, the 4X150D has a rated plate dissipation of 150 watts.

For further information or for consultation about your power tube needs write our application engineering department.

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Eimac TUBES

COMMUNICATION REVIEW

Privately-Owned Microwave Circuits and Telephone Company Facilities

By JEREMIAH COURTNEY*

THE connection of privately-owned microwave circuits with telephone company facilities has become a matter of extreme importance to the pipeline and power utility industries, now the principal users of microwave systems. With the grant of the first microwave circuit in the Special Industrial radio service to the Freeport Sulphur Company of New Orleans, the subject is receiving widespread attention.

Freeport Sulphur Precedent: Before passing to a consideration of the main problem, a preliminary comment on the significance of the FCC grant to Freeport Sulphur may be indicated. First, this established a precedent under which any company engaged in "production, construction, fabrication, manufacturing or similar processes" can use microwaves to inter-connect offices in remote or sparsely settled areas not only with each other but with an office that may be located in a very large metropolitan area. Second, such grants for point-to-point operational communications use may be had without regard to a company's use or non-use of a mobile system.

This action marks a long step forward in the direction of putting Special Industrial radio users on a parity with petroleum and power companies, and others who may use microwave systems. That such a result is in the public interest is perhaps best indicated by the fact that the primary criterion for Special Industrial grants — engagement in production, construction, fabrication, or manufacturing activities — is a description of the companies that represent the collective industrial might and genius of the Country. If microwaves can contribute to the efficiency and economy of operations of these companies, without causing interference to any systems of higher priority, there would appear to be no reason to deny such use to the companies upon whom we collectively depend for our high level of national productivity.

Significance of Interconnections: Having come thus far in extending the use of microwave circuits, however, the question arises as to whether or not the petroleum, power, railroad, or other industrial microwave users can look forward to the interconnection of private microwave circuits with the telephone company's PBX boards at the terminal offices.

The answer is highly important, and may indeed determine if microwave use is to be economically practical where there is a large office at one or both ends of the microwave circuit, and a number of telephones from which intra-company radio calls must be made. Under such conditions, if the switchboards cannot be connected to the microwave circuit, it will be necessary to purchase, install, and maintain separate telephone instruments and PBX boards just to handle radio calls. This may add a six-figure item to the investment in the microwave equipment.

Telephone Companies' Position: The problem arises because the telephone companies may be expected, initially at least, to take the position that connecting private radio facilities with telephone company facilities will not be permitted under their tariffs[1] (except where the circuits involved terminate at hazardous or inaccessible locations). The usual reason assigned in such cases is that the interconnection would result in impaired telephone service because of the divided responsibility and control with respect to the equipment. This position indicates an offer to provide the entire communications facility in which the microwave user is interested — on common carrier frequencies and on a charge basis. Since this last offer is seldom acceptable because of comparative cost considerations, the question then becomes one of the reasonableness of the tariff provision prohibiting the interconnection of the private microwave circuit with telephone company facilities.

The FCC's Jurisdiction: The first reaction of the prospective microwave radio user may be to turn to the Federal Communications Commission for relief. Neither the Communications Act of 1934, as amended, nor the regulations of the Federal Communications Commission issued pursuant thereto, however, require telephone companies to interconnect privately owned microwave systems with telephone company switchboards. The jurisdiction of the FCC over the interconnection of facilities is limited by statute to ordering interconnection of common carriers engaged in interstate or foreign communication by wire or radio. [Communications Act of 1934, as amended, Section 201 (a)]. It does not in terms extend to ordering the establishment of physical connections between the facilities of a common carrier and those which are privately owned.

Under Section 214 (d) of the Communications Act, the Commission is given a residual power to require any carrier "to provide itself with adequate facilities for the expeditious and efficient performance of its service as a common carrier" but it is doubtful that this Section would apply to the problem under consideration, without a convincing showing that it is not otherwise feasible to provide the desired service.

The FCC's Interest: If a complaint were made to the FCC because of the telephone company's denial of the interconnection sought, it seems probable, therefore, that the FCC would decline jurisdiction of the matter.

This despite the fact that in Docket No. 8963—*In the Matter of American Telephone and Telegraph Company, Charges and regulations for television transmission services and facilities*, decided December 21, 1949, the Commission concluded that a Bell System tariff seeking to deny the furnishing of intercity video transmission channels to a customer who planned to connect such channels either directly or indirectly with intercity video channels not furnished by the Telephone Company (except where the Telephone Company did not have the required facilities available) was unjust, unreasonable and therefore unlawful under Section 201 (b) of the Communications Act, prohibiting unjust and unreasonable charges, practices, classifications, and regulations by com-

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[1]Briefly, a tariff is a statement of the conditions, including rates, under which the carrier offers service to subscribers.

The IRE Vehicular Group Meeting

AN ON-THE-SPOT ACCOUNT OF EVENTS AND PAPERS GIVEN AT THE 1952 MEETING OF THE PROFESSIONAL GROUP ON VEHICULAR COMMUNICATIONS

THE third annual meeting of the IRE Professional Group on Vehicular Communications, held December 3 to 5 at the Hotel Statler in Washington, D. C., was notable for many good reasons. Most important among the factors responsible for its singular success, however, were probably the quality of the papers presented at the meeting and the intense interest shown in the technical sessions. During these sessions, the equipment exhibit room was virtually empty except for those in attendance at the booths — an almost unheard-of phenomenon. Most of the engineers who made the trip to Washington attended every technical session, displayed courteously anxious interest as the papers were given, asked intelligent questions, and went away discussing the subjects of the meeting rather than the recreation of the evening before.

Theme of the meeting was spectrum conservation. Crowding in many services has become virtually intolerable, and the only reasonable means remaining for alleviating congestion is the provision of more channels. Since it is unlikely in the extreme that more spectrum space will be allocated in the forseeable future to the mobile services, then channel-splitting offers the only way to obtain these extra frequency assignments. Thus, the possibilities of split-channel operation have been discussed in recent years with ever-increasing interest. The problem is now reaching a head, which probably accounts in part for the unusual spirit displayed at the meeting.

Within the last few years, laboratory and field tests have been made on split-channel equipment exploring various aspects of its performance. Successful field tests have been in progress on 20-kc. operation at 25 to 50 mc. for some time; although no official action has been taken, it is generally agreed that such spacing will be standardized in that band. Results of split-channel tests in the higher bands, while more or less uniformly encouraging, could not be tied together to obtain an inclusive and conclusive picture because of widely varying test conditions. Also, there was little information available on *comparative* performance of wide and narrow-band systems. As congestion increased, claims and counter-claims were made. Finally, the FCC requested definitive information on the problem from the Joint Technical Advisory Committee. The JTAC Subcommittee on Land Mobile Channel Allocations, under chairman Fred Budelman of Budelman Radio Corporation, was charged with supplying answers to the following questions:

1) Is it feasible, considering recent research and developments in land mobile radio equipment, to reduce the separation between assignable frequencies in the 152 to 162-mc. band, preferably to some submultiple of 60 kc. such as 30, 20, 15, or 10 kc., in order that stations using improved equipment may operate on frequencies spaced closer together?

2) Assuming that narrow-band equipment is technically and economically feasible, what are suggested methods to be followed in the transition from the present 60-kc. separation to a narrower separation in the 152 to 162-mc. band?

Members of the subcommittee, in addition to Mr. Budelman, consist of the following engineers: A. C. Dickieson and Kenneth Bullington, Bell Laboratories; D. M. Heller, Bendix; R. C. Davis and G. W. Sellers, Federal Telephone and Radio; C. M. Heiden, R. P. Gifford, and N. H. Shepard, General Electric; D. E. Noble, M. E. Bond, and J. F. Byrne, Motorola; A. D. Zappocosta and H. E. Strauss, RCA; and A. A. Macdonald, Westinghouse. These gentlemen have been working assiduously to formulate proposed specifications for the 150 and 450-mc. bands, and have conducted a series of field tests for comparison purposes.

First Technical Session: Mr. Budelman, in his capacity as chairman of the JTAC subcommittee and chairman of the IRE Professional Group on Vehicular Communications, opened the Washington meeting with a report on the work of his subcommittee. While no definite conclusions had been reached at that time, he stated, real progress had been made, and the goal was not far away. It is expected that the work will be completed sometime in the spring.

Following these introductory remarks, Kenneth Bullington of Bell Laboratories spoke on "Frequency Economy in Mobile Radio Bands". He pointed out the factors affecting the usefulness of mobile radio systems, and emphasized the intermodulation problem. Mr. Bullington stated that intermodulation interference increases rapidly with increasing channel density, and is a limiting factor on frequency economy. He concluded that more can be gained by systems engineering techniques than by potential equipment improvements.

D. M. Heller, Bendix Radio Corporation, then talked on "Technical Considerations Governing the Choice of Channel Spacing in Mobile Communication Bands". Mr. Heller emphasized manufacturing considerations, concluding that the preferred approach to channel spacing choice is to design equipment for the closest possible spacing. This involves closer frequency and deviation control and higher standards of maintenance.

A report on a "Field Test of Split-Channel 50-Mc. Systems" was given by W. M. Rust, Jr., of the Humble Oil Company. Mr. Rust described tests conducted by the National Petroleum Radio Frequency Coordinating Association, using 20-kc. channel separation at 50 mc., and the results of those tests. It was concluded that equipment is now commercially available which gives satisfactory performance for such operation, that the operating range of narrow-band equipment is equal to or better than that of wide-band units, that 5-kc. deviation is more suitable for narrow-band operation than 7½ kc., and that the only effect on maintenance of narrow-band equipment is that control of center frequency and maximum deviation is more important than with wide-band units.

Jerry Stover, of Communications Engineering Company, wound up the first technical session with a description of "Operational Experience with a Split-Channel 50-Mc. System". Mr. Stover's talk was concerned primarily with the problems of changeover from wide-band to narrow-band equipment, and what can be done to integrate new narrow-band systems into regions where wide-band systems are in operation.

At the luncheon following the first session, Dr. W. R. G. Baker, chairman of the IRE Professional Groups Committee, gave the keynote address. Dr. Baker spoke on "Electronics — Promise and Reality", reviewing the forces lending impetus to technological advancement, and emphasizing that the achievements possible can be realized only through intelligent research and training programs.

Second Session: The first-day afternoon session was opened by H. E. Strauss of RCA with a paper on "Channel Spacing Considerations in the 152 to 174-Mc. Band". He described

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150 to 3,700-Mc. Performance Tests

A COMPARISON OF 2-WAY FM RADIO PERFORMANCE AT 150, 450, 900, AND 3,700 MC., WITH AN EVALUATION OF RESULTS — *By* W. RAE YOUNG, JR.*

FROM the beginning of mobile radio-telephone services offered by the Telephone Companies, both "general" and "private-line" types, it has been apparent that the number of channel frequencies then allocated for these uses would not be sufficient to meet the service needs in the near future.

The bulk of these needs will be for service in urban and suburban areas, where business activities are concentrated. These areas are now served on a few individual FM channels in the vicinity of 150 mc. However, a larger number of channels, needed to meet anticipated demands and to develop a more efficient system, are not to be found in the 150-mc. region. This space is already allocated fully and permanently to a variety of other services. In fact, this situation extends up to about 400 mc. The larger number of channels for these services apparently will have to be found, therefore, above 400 mc.

However, it is essential to know whether these higher frequencies would be suitable for urban mobile telephone service, or whether there exists an upper limit to the suitable frequencies. In order to answer these questions, a series of tests has been made to compare the adequacy of coverage that could be provided at several representative higher frequencies. These tests were conducted in and around New York City.

Problem of Evaluation:

It became apparent early in the tests that it would neither be practical nor accurate to compare service results for the different frequencies by the method of determining the coverage at the various frequencies, and then comparing these. This would have required, among other things, that *coverage* be defined precisely and then measured accurately in order to determine the differences with the desired accuracy.

Instead, it was recognized that commercial coverage is at present considered to extend into areas wherein a small percentage of the locations will have less than commercial grade of transmission. This might be ten per cent, for example. It was further recognized that, while there existed a trend of performance with frequency, comparative tests at any one location showed variations from that trend. Thus, even if transmitter powers were adjusted so as to offset the transmission effects of that trend, performance at any location would not be equal at all frequencies. Even if one frequency gave relatively poor transmission in one location, it might give good transmission at another location. While the locations of poor transmission were found to be different at the various frequencies, the number of such locations would be the same at all frequencies, provided the trend had been offset by adjustment of transmitter power.

Viewing the problem in this way, it was sufficient to test at enough locations in representative territory to establish this trend in a statistical manner.

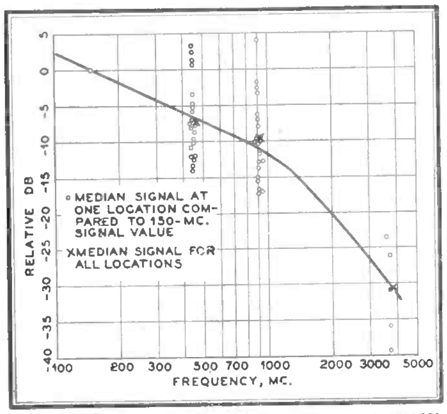


FIG. 1. MEDIAN SIGNAL LEVELS VS. FREQUENCY FOR THE SAME DISTANCE AND RADIATED POWERS

Other problems in evaluating differences in suitability of different frequencies lay in how to take into account differences in practical antenna gains and differences in frequency stability. These will be discussed in the next sections.

Overall Results:

The results of many measurements of path loss between a land radio transmitter and a mobile receiver establish a trend of loss increasing with frequency. This is illustrated in Fig. 1 by the crosses which show the strengths of the received signal at higher frequencies as compared with those at 150 mc. The derivation of the values given by the crosses will be discussed in a later section. In the other direction of transmission it appears justified, based upon reciprocal relationships, to assume that path losses from mobile transmitter to land receiver will follow the same trend.

However, although the received signal is seen to decrease with frequency, the amount of received signal which is required to produce satisfactory communication also changes with frequency. The median level of signal required at a mobile or land receiver at various frequencies to override RF noise is given in Fig. 2. The dots here represent the average of many measurements.

Transmitter power required to achieve the same service result at various frequencies has been derived by taking into account the changes of path loss with frequency and also the changes of signal required with frequency. Fig. 3 shows the amounts of power that are required in order to achieve the same coverage in all cases as is now obtained at 150 mc. with 250 watts of land transmitter power radiated from a dipole. As shown, the use of an antenna having gain can appreciably lower the land transmitter power that is required. The mobile transmitter power is much less than required of a land transmitter because of the assumption that there are six land receivers located appropriately in the coverage area, rather than just one.

It is apparent from Fig. 3 that the required transmitter power is a minimum in both directions of transmission at around 500 mc. It is also apparent that above this point the required transmitter power increases rapidly with frequency.

A word of explanation is needed about the gain antenas which were assumed in one of the curves in Fig. 3. These are antennas which tend to concentrate radiation toward the horizon in all directions. Limits for the amount of gain were based upon the considerations 1) that a set of radiating elements greater than about 50 ft. in extent would be impractical to build for this service, and 2) that the vertical width of the beam should not be less than about 2 degrees in order to assure that valleys and hilltops would be covered. The amounts of gain possible within these limits are as follows:

Frequency Mc.	Gain, db
150	8
450	13
900	15
3,700	15

The mobile antennas were assumed to be quarter-wave whips or the equivalent.

Use of gain antennas for the land receivers would result in lowering still fur-

*Bell Telephone Labs., Inc., 463 West Street, N. Y. C. This paper appeared also in the *Bell System Technical Journal* for November, 1952.

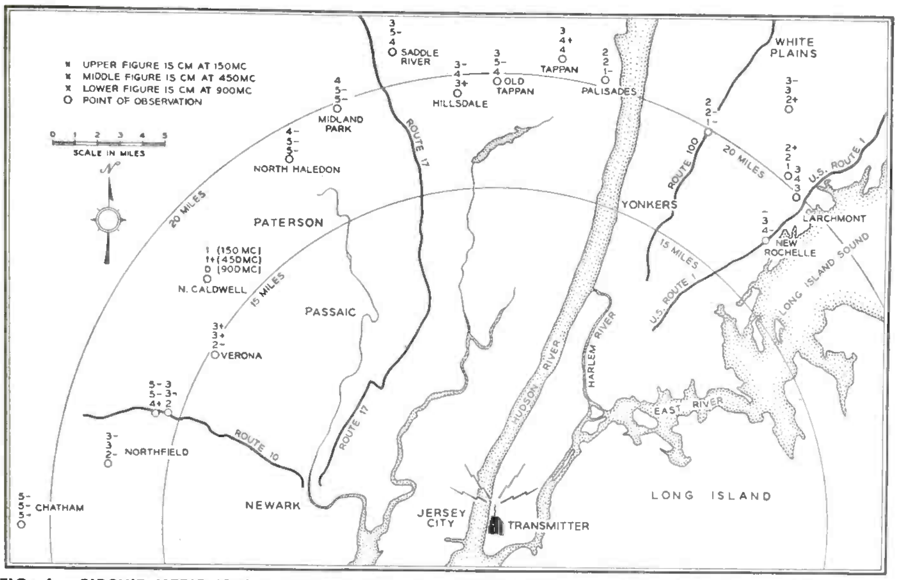


FIG. 4. CIRCUIT MERIT (CM) OBSERVATIONS. 0: UNDETECTABLE; 1: UNINTELLIGIBLE; 2: POOR, JUST READABLE; 3: FAIR, COMMERCIAL QUALITY; 4: GOOD, NO OBJECTIONABLE IMPAIRMENT; 5: EXCELLENT

ther the required mobile transmitter power. This is not shown on Fig. 3 because the amount of reduction cannot be accurately stated on the basis of present knowledge. It appears certain that the reduction will be at least equal to the antenna gain, and may be appreciably more than this, as indicated later.

The system modulation and pass-band were assumed in the above discussion to be the same at all frequencies. This would not be realistic if the tolerance allowed for frequency instability were a fixed percentage of operating frequency. It may be justified, however, because the necessity for frequency economy and for best transmission performance demands better percentage stability at higher frequencies.

A spot check of transmission, observing circuit merits by listening, has been made to determine the validity of the above results in a very general way. Land transmitter powers were adjusted so that the equivalent dipole power at 450 mc. was 3 db less than at 150, and power at 900 mc. was 1 db less than at 150 mc. This approximates the powers shown on the dipole curve in Fig. 3. The map, Fig. 4, shows the results of this test. While the comparison of circuit merits generally shows a preferred frequency at any given location, the performance appears to be about equal when all locations are considered.

Test Equipment:

Tests of transmission outward from the land transmitting station were made on signals radiated from antennas on the roof of the Long Lines Building, 32 Avenue of the Americas, New York City. These antennas were 450 ft. above ground. One of the existing mobile service transmitters served for the 150-mc. tests. Special experimental transmitters were set up for the 450, 900, and 3,700-mc. tests. All were capable of frequency modulation.

The mobile unit was a station wagon equipped to receive and measure signals

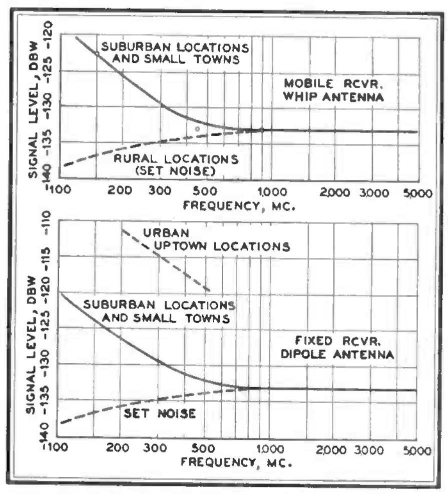


FIG. 2. MEDIAN SIGNAL LEVELS REQUIRED TO OVERRIDE RF NOISE AT RECEIVING LOCATIONS

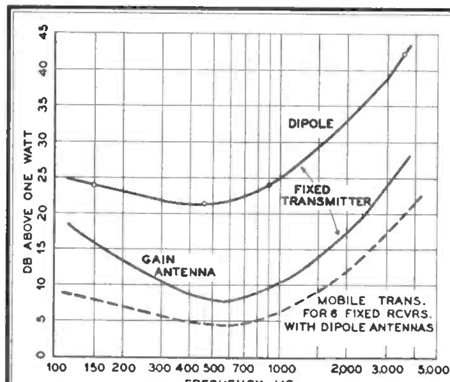
at the various frequencies. The receiving equipment was arranged for rapid conversion from 150 to 450 to 900 mc. The bandwidth (about 50 kc.) and system modulation (±10 kc.) were identical at all three frequencies (equal to the existing standards at 150 mc.). The 3,700-mc. tests were handled separately. It was not possible to employ the same bandwidth and deviation, but this does not invalidate the comparison of signal propagation at the various frequencies.

A most useful tool in making these measurements was a device known as a level distributor recorder, or simply LDR. This was built especially for these tests and is similar to its forerunners which have been used in the past for measuring atmospheric static noise. The LDR, in combination with a calibrated radio receiver, is capable of taking as many as twenty instantaneous samples of radio signal strength per second, sorting the samples by amplitude, and rendering information on a batch of samples from which a statistical distribution curve can be plotted. The LDR was also used for measuring the statistical distribution of audio noise in the output of the radio receiver. The LDR was, in this case, associated with a special converter whose characteristics resemble those of a 2B noise measuring set.

No arrangements were made for measuring radio propagation from mobile units to land receivers. It was felt that the comparison by frequencies would be substantially the same as in the outward direction of transmission. It does not follow, however, that the background electrical noise, against which an RF signal must compete, will be the same at mobile and land receivers. Strength of an RF signal required at land receivers for satisfactory transmission was measured at several typical locations.

Signal Strengths, Path Losses:

The first factor in evaluating mobile radio transmission is the strength of the RF signal which is received. This is inversely related to the loss in the RF path. The mobile units of a mobile system are either moving around or, if stationary, are located at random. Since the effects of the many geographical features, buildings, and the like, which influence propagation can combine differ-



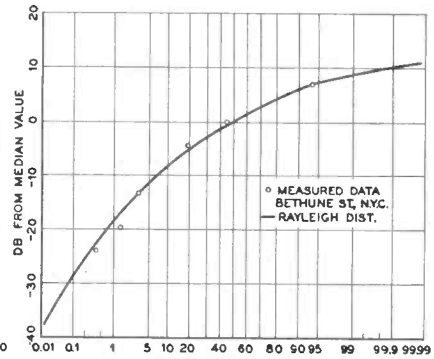
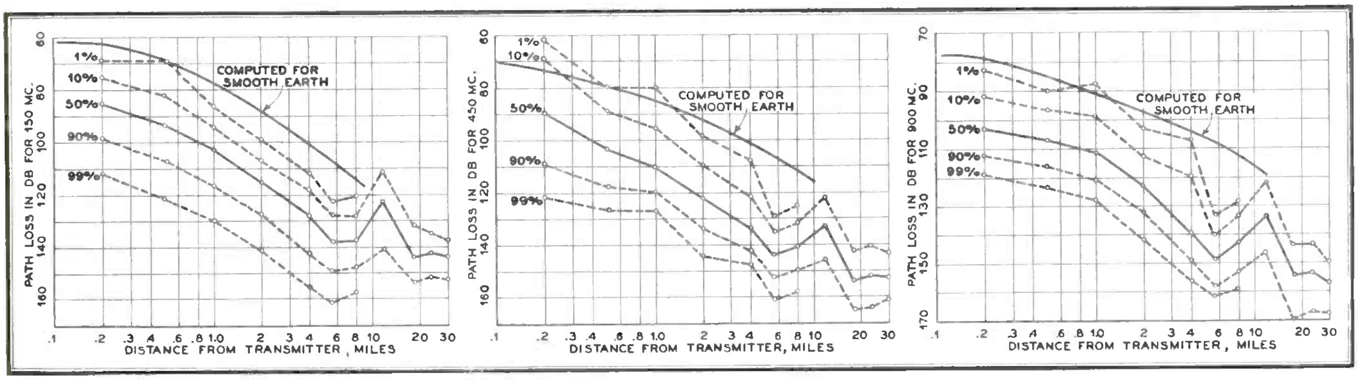


FIG. 3. LEFT: POWER REQUIRED AT VARIOUS FREQUENCIES FOR SAME SERVICE AS IS OBTAINED WITH 250 WATTS AT 150 MC. FIG. 5, RIGHT: TEST SAMPLE SIGNAL-STRENGTH DISTRIBUTION IN SMALL AREA

ently for different locations of a car, even where the locations are only a fraction of a wavelength apart, the only meaningful measure of signal strength is a statistical one. Such statistical answers were obtained by making and recording many instantaneous samples of field strength



FIGS. 6, 7, 8. PATH LOSS MEASUREMENTS FOR 150, 450, AND 900 MC., COMPARED WITH COMPUTED SMOOTH-EARTH CURVES, SHOW ABOUT 30-DB DIFFERENCE

with the aid of the LDR. mentioned above.

It is of interest to note that whenever the sample measurements were confined to a relatively small area, say 500 to 1,000 ft. or less in extent, the amplitude distribution of these samples tended strongly to follow along the particular curve known as a Rayleigh distribution. Such a curve and a typical set of experimental points are shown in Fig. 5. The same distribution was obtained for all the frequencies tested, including 3,700 mc. The rapidity of signal fluctuation, as the car moved, was proportional to frequency, but this does not affect amplitude distribution. Such a distribution could have been predicted if it had been postulated that the transmitted signal reached the car antenna by many paths having a random loss and phase relationship. It is thus inferred that in general the signal reaches a car by many simultaneous paths.

With the shape of the distribution known, only one other value need be given in order to specify the propagation to such a small area. This might be the median, the average, the rms, or any single point on the curve. The one used most often here is the median; that is, the value which is larger than 50% of the samples and smaller than the other 50%. Measurement of the median value by this statistical method was found to be accurately reproducible, and therefore is presumed to be reliable. Successive batches of 200 samples each, all covering the same test area, yielded median values which differed not more than .5-db when none of the conditions changed; *i.e.*, transmitter power, antenna gain, and receiver calibration remained the same. This accuracy may seem surprising when it is realized that individual samples differ frequently by 10 db, and often as much as 30 to 40 db.

It was presumed at the outset of the tests that the different frequencies would exhibit different propagation trends with distance. For this reason the samples have been grouped by distance. In presenting these results, it was convenient to express the measurements of received RF signal in terms of path losses. By this it is meant the loss between the input to a dipole antenna at the transmitter and the output of a whip antenna on the test car. These path losses will have, of course, the same distribution as the received RF signal.

The results of the path loss measurements are given in Figs. 6, 7, and 8 for 150, 450, and 900 mc. respectively. These values represent the loss between

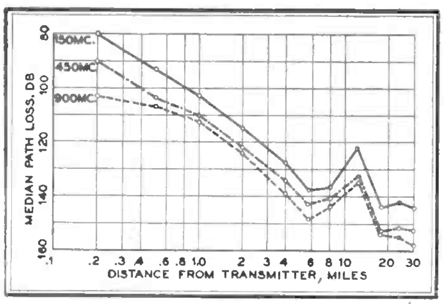


FIG. 9. MEDIAN CURVES FOR THE 3 FREQUENCIES ABOVE REPLOTTED TO SHOW COMPARATIVE LOSSES

the input to a half-wave dipole antenna at one end of the path and the output of a quarter-wave whip at the other end. They are shown here as a function of distance from the land station. For distances under 10 miles, the data are the result of tests in Manhattan and the Bronx. For each distance a test course was laid out approximately following a circle with that distance as a radius. The data for 10 miles and greater distances were obtained on two series of tests along radials from the land transmitter, one of which followed Route 1 through New Rochelle, N. Y., and the other followed Route 10 toward Dover, N. J. For reference, a curve has been given on each of these figures which shows the computed loss based upon the assumption of smooth earth.

A curve labeled 1% means that in 1% of the sample measurements, the loss was less than that indicated on the ordinate. The meaning of the labels on the other curves is similar. The curve labeled 50% is, of course, the median.

It will be apparent that the assumption of smooth earth is not applicable to the area tested. The data for median losses are in the order of 30 db greater than the value computed over smooth earth. This additional loss may be thought of as a shadow loss arising from the presence of many buildings and structures.

The distribution of losses given in these three curves is wider than the Rayleigh distribution, Fig. 5. This is because the data for each distance are a summation over many different locations rather than a set of samples covering one location.

The data for ten miles and farther from the transmitter were taken on routes through suburban areas. The losses at 12 miles appear to be less than the average trend indicated by the curves. This is because data taken at the top of the First Orange Mountain weigh heavily at this distance. It is of interest to note that the losses at distances of ten miles and over are 6 to 10 db less than might have been predicted from the trend at smaller distances, where the measurements were made in city areas. This probably reflects the fact that there is a considerable difference in the character of the surroundings, such as height and number of buildings in the suburban territory as compared with the city itself.

The median curves of loss have been replotted for three frequencies in Fig. 9. This permits a better comparison with

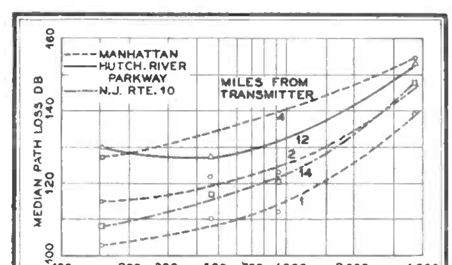


FIG. 10. PATH LOSS VS. FREQUENCY FOR VARIOUS FIXED DISTANCES FROM TRANSMITTER LOCATION

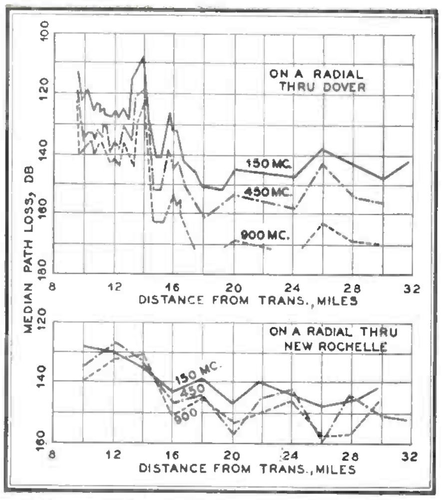


FIG. 11. RELATIVE PATH LOSSES MEASURED AT GREATER DISTANCES IN SUBURBAN LOCATIONS

frequency. Except at locations very close to the transmitter, the performance at the various frequencies seems to differ by an essentially constant number of db, while exhibiting the same trend with distance. The similarity between frequencies is apparently much greater than the similarity between the median value and the value computed over smooth earth for any given frequency.

It was not possible to get complete enough data to plot a curve for 3,700 mc. similar to the ones mentioned above. The test setup at this frequency was limited by transmitter power and receiver sensitivity. Only those locations for which path loss was relatively low could be tested. A comparison of results at these locations is given in Fig. 10. The curves labeled 1 mi., 2 mi., and 4 mi. for Manhattan are the median values obtained along test routes which followed circles of 1, 2 and 4 miles radius from the transmitters. The other curves refer to selected small areas at greater distances on the Hutchison River Parkway and New Jersey Route 10, as indicated. Although the data at 3,700 mc. are not extensive, the trend with frequency seems clear.

More specific data for path losses measured along the routes toward Dover and New Rochelle are given in Fig. 11. Each value plotted here is the median of about 200 samples taken in a small area at the distance indicated. The strong effect of the First and Second Orange Mountains at fourteen and sixteen miles on the Dover route is of interest.

The coverage desired in these mobile telephone systems extends into suburban locations. It follows that a comparison of coverage by the various frequencies should be based upon measurements taken in the suburbs. The data from the New Rochelle and Dover series have been used as a basis for the points and the curve given in Fig. 1. Each of the circle points shows the path loss at a given frequency relative to that at 150 mc. for a particular location. Their spread indicates that the comparison of frequencies is different at different locations. The crosses are the median values of these points, so placed that there are as many points above as below. The points for 3,700 mc. are taken from data of Fig. 10. The crosses in Fig. 1 are considered to be the most reliable all-around comparison of propagation at the different frequencies.

Speech Noise vs. Signal Power:

Speech-to-noise ratios were measured at all test locations by the use of the level distribution recorder as described earlier. During the course of any given test the audio noise from the receiver varied considerably, and these variations were recorded on the LDR. It was found by correlation between subjective observations of circuit merit and the median value of noise that the latter is equivalent in noise effect to a steady random noise of the same value. In the FM receiver, the level of speech is essentially not affected by the strength of RF signal. Thus, a measurement of the output noise is directly related to the speech-to-noise ratio. The speech-to-noise ratios given here are computed from noise measurements by assuming that speech of −14 vu level is applied to the system at a point where one milliwatt of 1,000 cycles tone would produce a 10-kc. frequency deviation. The strength of the speech signal at the receiver output is expressed in the same units as are used for the noise.

As might have been expected, the median speech-to-noise ratios correlate strongly with the amounts of RF signal received at the various locations. This correlation has been evaluated in order that the most likely relationship between speech-to-noise ratio and received RF signal may be known for the different frequencies. These are shown in Fig. 12, where each circle represents the median speech-to-noise value measured at one test location plotted against the median RF signal received at that location. The solid lines have been drawn in to show the trend. The bending at the top of the curve is inconsequential. It represents only the limit imposed in the test setup by tube microphonic noise, vibrator noise, etc. The curves show, for example, that in order to produce a commercial grade of transmission, which requires a 12-db speech-to-noise ratio, the median RF signal must be 122.5 db below 1 watt at 150 mc.

The data given in Fig. 12 pertain only to the suburban locations. Measurements in Manhattan have not been included, even though they indicate that larger signals are required, because the limit of system coverage is to be found in the suburbs. The data on the solid curves, Fig. 12, have been used to derive the curve in Fig. 2, which shows the value of RF signal required at the mobile receiver for a commercial grade of transmission. The dotted curve in Fig. 2, which shows the median signal required in locations where noise picked up by the antenna is less than set noise, is based on the assumption of an 8-db noise figure for a practical 150-mc. receiver, 11 db at 450 mc., and 12 db at 900 mc. and higher.

Measurements have been made of the effect of noise picked up by the antenna at land receiver stations. These are expressed here in terms of the carrier strength required for just-commercial grade of transmission (12-db speech-to-noise ratio) as compared with the value required when there is no antenna noise and only receiver noise is present. These comparison measurements were made by injecting a steady carrier into the receiver with an antenna connected normally, and again with a dummy antenna connected. Although these tests were made with a steady rather than ran-

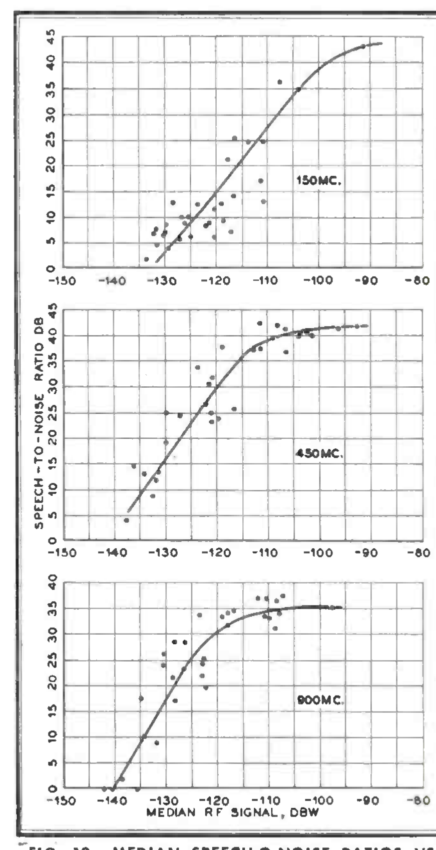


FIG. 12. MEDIAN SPEECH-O-NOISE RATIOS VS. MEDIAN RF SIGNAL LEVELS FOR 3 FREQUENCIES

domly varying signal, it is felt that the comparative results will apply to the random signal case as well.

Tests were made at 150, 450, and 900 mc., at four locations of interest, and with dipole and 7-db gain antennas. Not all combinations were tested, but enough to permit some interesting comparisons.

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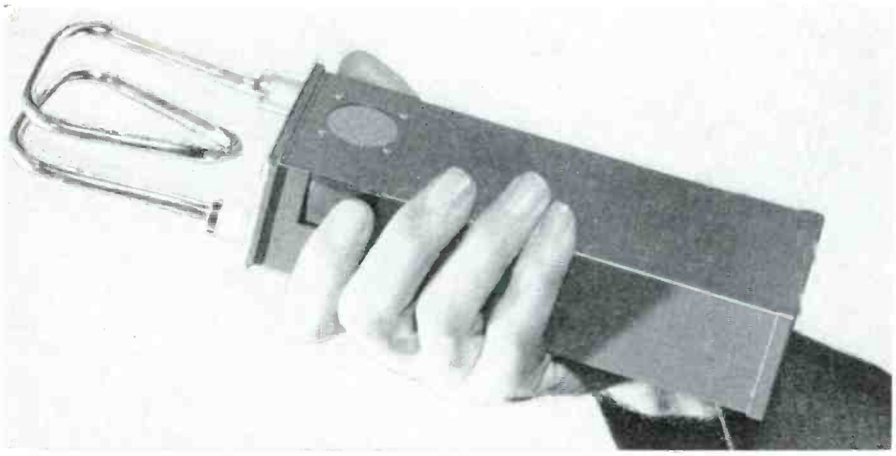

FIG. 1. COMPLETE TRANSMITTER AND ANTENNA FITS COMFORTABLY IN THE HAND, WEIGHS ONLY 29 OZ.

A Handie-Micro-Talkie

DESIGN DETAILS FOR SUBMINIATURE FM BATTERY-OPERATED TRANSMITTER — *By* WILLIAM J. WEISZ*

ONE of the more practical products made possible through the use of printed-circuit design techniques is the miniature Motorola Handie-Micro-Talkie unit, shown in Fig. 1. This is a portable FM transmitter, operating in the 152 to 174-mc. band, which produces 25 milliwatts of RF output but weighs only 29 ounces *including batteries*. Dimensions are 1⅞ by 2⅝ by 7⅜ ins. excluding the carrying handle, which doubles as an antenna. Although subminiature in design, its performance is far from diminutive; crystal oscillator control, full 15-kc. deviation, standard pre-emphasis, and communication voice-quality are all provided. It can be integrated perfectly into any standard 2-way FM system operating in the 160-mc. band.

Designed originally for railroad applications, Fig. 2, it has been extremely useful for car checking and train assembly. The miniature transmitter has proved itself also in a multitude of other applications. These include law enforcement, portable microphone work, production control in industrial plants, as in Fig. 3, construction projects, and other activities benefiting from dependable communication equipment small in size and light in weight. The unit fits easily into a coat pocket. Alternately, it can be supplied with a canvas carrying bag that can be attached to any belt.

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General Construction:

There is no separate ON-OFF switch provided. To transmit, the unit is held up so that the microphone is about two inches from the mouth, and the actuating switch located on the left side of the housing is pressed. All tubes in the transmitter are of the instant-heating filamentary sub-miniature type. The push-to-talk microswitch applies power to these tubes.

Fig. 4 is a block diagram of the assembly. As can be seen, 8 tubes are employed, consisting of a crystal oscillator, a modulator, 5 doublers, and a power output stage. All components of the transmitter, excepting batteries and microphone, are mounted on a plated-circuit Bakelite chassis. This chassis, shown in Fig. 5, is ¾ by 2¼ by 6¾ ins. overall, with all components mounted.

The battery supply consists of two 30-volt hearing-aid type B batteries connected in series, and two 1.5-volt hearing-aid type A batteries connected in parallel. The transmitter draws 12 ma. from the 60-volt source and 430 ma. from the 1.5 volt battery, for an output

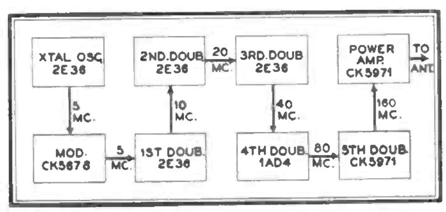
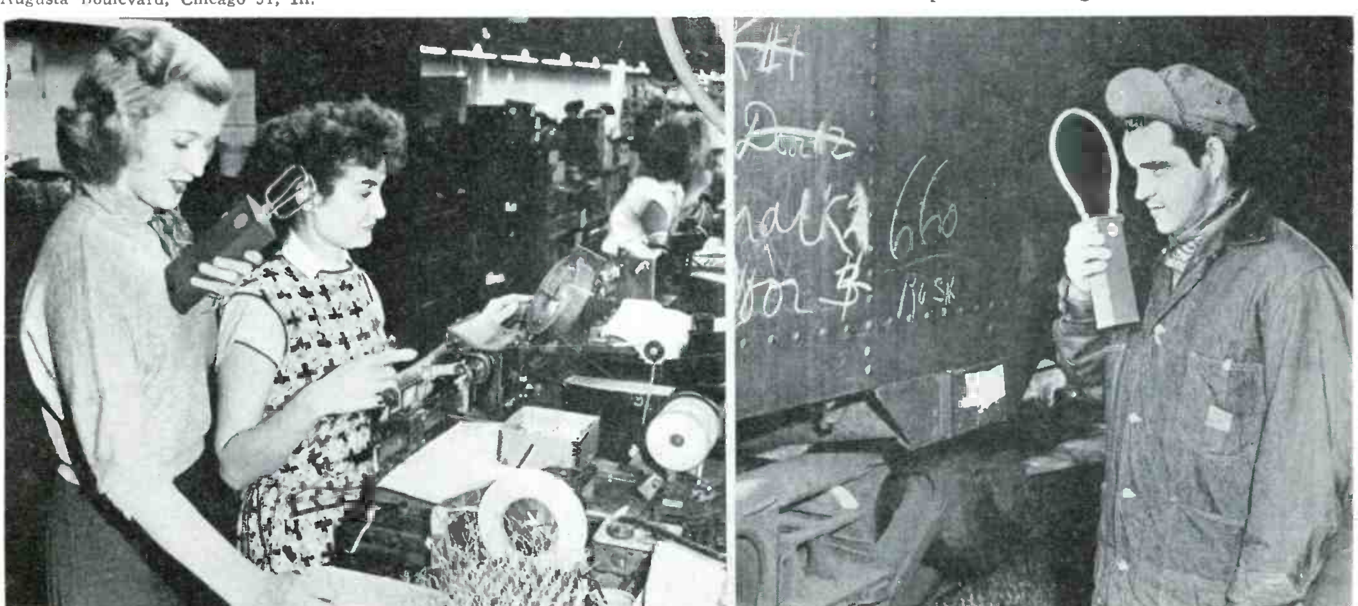


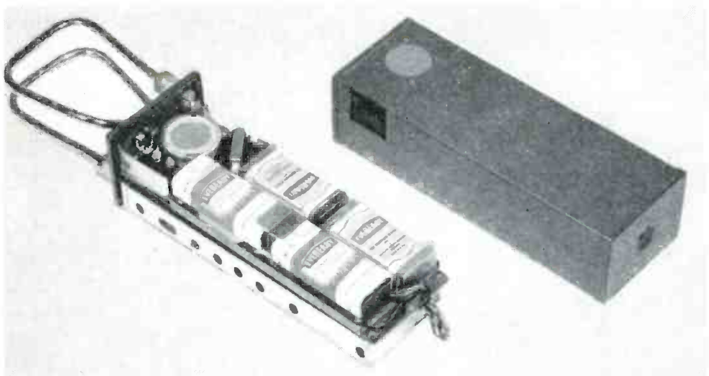
FIG. 4. ONLY SUBMINIATURE TUBES ARE USED

power of 25 milliwatts. The same Bakelite chassis, incidentally, becomes a 250-milliwatt RF power unit when connected to a 120-volt supply and two tubes are replaced with different types.

Battery replacement is extremely simple. Loosening one screw at the bottom



FIGS. 2 AND 3. THE COMPACT TRANSMITTER, WITH SURPRISINGLY GREAT COMMUNICATION RANGE, SHOULD HAVE A VERY WIDE FIELD OF APPLICATIONS



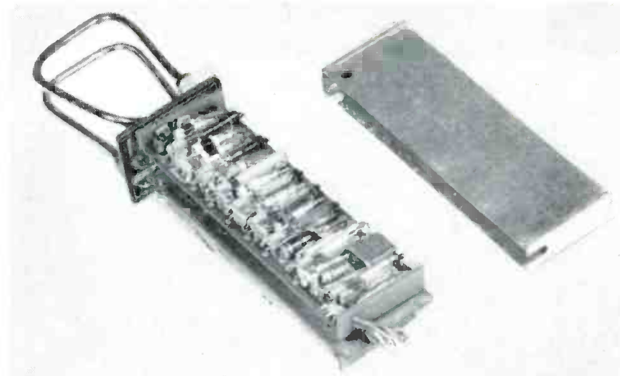


FIG. 6, LEFT: HOUSING REMOVAL REVEALS BATTERIES, TALK SWITCH, AND MICROPHONE. FIG. 7, RIGHT: OTHER SIDE HAS SHIELDED TRANSMITTER CHASSIS

of the housing permits access to the batteries, which are held in place by spring clips, as shown in Fig. 6. The transmitter proper is in its own shielded enclosure, and is mounted on the opposite side of the chassis from the batteries, Fig. 7.

The chassis is an integral part of the front panel assembly. Holes are provided in the transmitter shield can for insertion of a tuning tool. Thus, when the shield can base is removed, exposing the tube grid terminals, the unit can be aligned without obtaining access to the Bakelite chassis and without removing the transmitter section from the front panel-chassis assembly. The front panel-housing junction is gasketed and the microphone grill is backed up by waterproof sheeting, so that the entire unit is weatherproofed for use under all climatic conditions.

The main factor in reducing the size of this unit was the elimination of ordinary wiring and construction techniques, and substitution of the Motorola PLAcir process of plated circuitry. Except for antenna and power input leads, all wiring is plated on a Bakelite chassis. As Fig. 5 shows, the transmitter is laid out in one plane, permitting the use of a single flat piece of Bakelite as a chassis. After all the holes for component leads are punched out of the piece, the circuitry is plated on both sides. Component parts are then dropped into place, with their leads through the plated holes, and soldered. The PLAcir process plates wiring on both sides of the chassis as well as completely through a hole to the other side. These two assets, unique to this process, account for the major reductions in size.

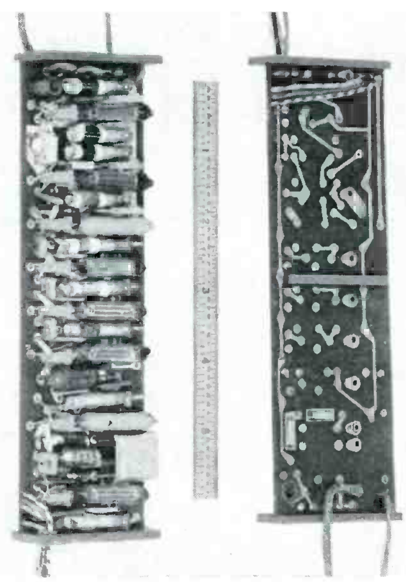


FIG. 5. DETAILS OF COMPLETED CHASSIS UNIT

The Plating Process:

The circuits are laid out by means of a screen, although it is possible to do the same job by the offset method. First, a screen of the desired circuitry is made. The Bakelite (which should be NEMA XXXP or better) is drilled or punched. Note that this is done before plating. The piece is then degreased, and its surface roughened. To increase the humidity resistance of the Bakelite, high already if XXXP or better is used, the piece can be vacuum wax impregnated and centrifuged. If this is done, the surface must be roughened again. The piece is then fed into automatic printer, which squeegees a resistive ink through the screen onto the Bakelite where no plating is desired. This is done simultaneously on both sides of the piece. After the inking process, the piece is put into the plating tank. It remains in the tank for about 30 minutes while copper is deposited wherever there is no ink. Then, a silver flash is put on top of the copper, the ink is removed, and the piece is dipped in lacquer to complete the process. The finished circuit lines are generally made from 1 to 3 mils thick, and this thickness can be controlled quite accurately.

Three important objectives are achieved by punching and drilling the pieces before they are plated. In the plating process, the metal is deposited completely through the walls of all holes or punched sections, and onto the opposite side. In other words, an eyelet is plated right through the hole, as can be seen in Fig. 8. First, this provides connections from one side of the Bakelite chassis to the other without using any leads or components. The crossover problem is solved. This in itself is a major size-reducing factor, because it is not necessary to carry leads all over

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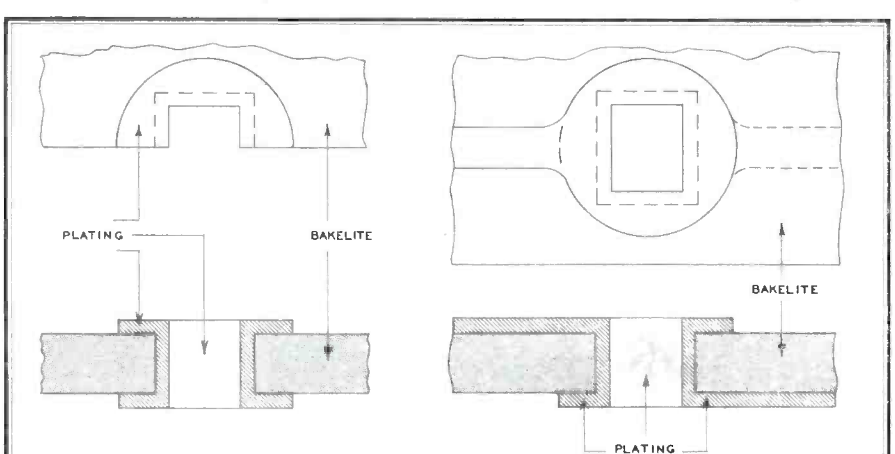


FIG. 8. HOW PLATING THROUGH HOLE IN THE BAKELITE CHASSIS FORMS A TIE POINT OR CROSSOVER

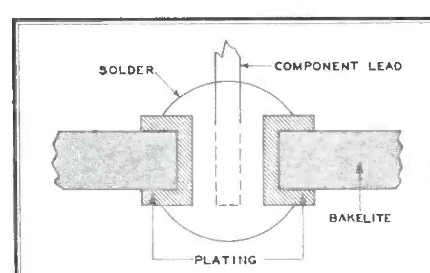
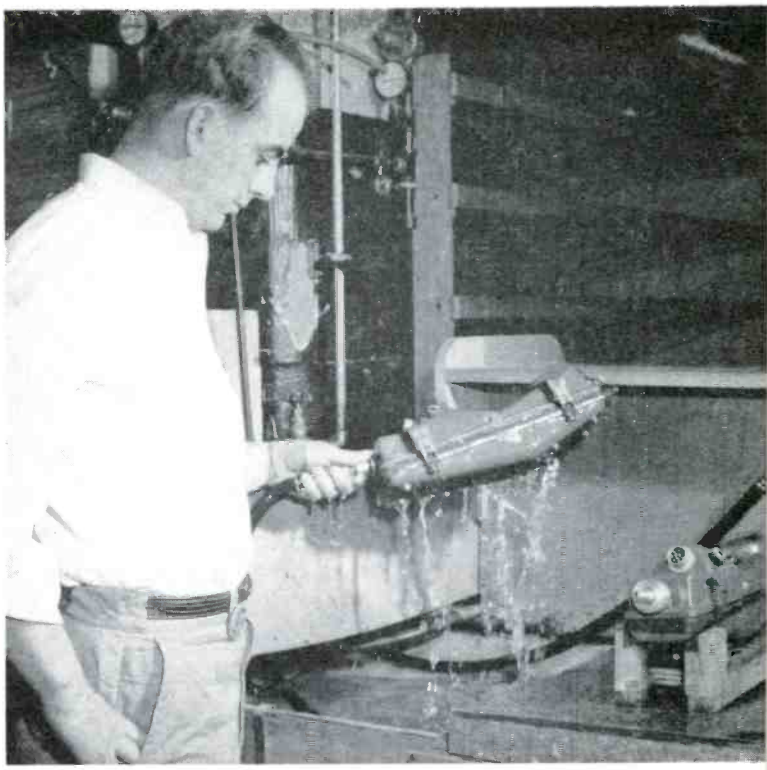


FIG. 9. HOW TYPICAL SOLDERED JOINT APPEARS

Details of the PRC-6

A PRECISION SUBMINIATURE FM TRANSMITTER-RECEIVER DESIGNED FOR LARGE-QUANTITY PRODUCTION

By Francis T. Koen and Ralph C. Sprague*



EACH PRC-6 IS CHECKED FOR LEAKAGE AT 3½ LBS. AIR PRESSURE

ALTHOUGH, in actual use, the PRC-6 hand-carried FM transmitter-receiver is new, the development and design was started in 1947, under a Signal Corps contract awarded the Raytheon Manufacturing Company. The work was carried out in collaboration with Signal Corps engineers at the Fort Monmouth Laboratories. Under this contract, 16 units were produced for field testing. Requirements as to weight, performance, and operating frequencies and the shift from AM circuits used in the World War 2 predecessor of this unit to FM circuits in the new one called for radical departures from familiar design concepts.

Some idea of the magnitude of this project in terms of perfecting new manufacturing, assembly, and testing techniques is conveyed by the fact that the complete transmitter-receiver chassis, with 13 tubes and 12 tuned circuits, is smaller and lighter than the dry batteries which operate it.

Specifically, the assembled chassis measures 5 by 2½ by 2 ins., and weighs 1.3 lbs., while the batteries are 7¼ by 2½ by 2¾ ins., and weigh 2.5 lbs. Transmitter output is .25 watt. Receiver characteristics show better than 1 microvolt sensitivity with signal +noise/noise of 10 db. Weight of the complete unit, as illustrated on the front cover, is 6½ lbs.

Procurement Was Major Problem: Our first contract for PRC-6 production was awarded at a time when all the usual sources of supply were already loaded with Government business. But William Cone, our purchasing agent, had an answer to that situation, drawn from his experience in the last war. He located the necessary skills and facilities outside the radio industry, and we undertook to educate management groups in our particular requirements. Between our assistance and their cooperation, we had components coming in months before we could have obtained them from the regular suppliers.

For example, Trifari, Krussman and Fishel, manufacturing jewelers in Providence, R. I., proved to have expert workers and equipment which solved some of our most difficult problems. We had crystals coming from American Crystal Company in Kansas City at a time when there was no prospect of getting delivery from any other company. We got Ace Engineering Company in Philadelphia to build our screen rooms and filters, and so on down the line, until we had everything we required coming in from many different sources. Meanwhile, we set up to produce ourselves such items as crystal diodes, coils, and subminiature transformers.

Preassembly Inspection: The mechanical design of the PRC-6 chassis, and the assembly procedures we set up to attain fast, economical production are not adapted to reworking assemblies rejected in final test. Consequently, we put somewhat more than usual emphasis on incoming inspection.

We sort all resistors and capacitors according to per cent variation from specified values. This is done in a machine built by Industrial Instruments, of Jersey City, and shown in Figs. 1 and 2. The operator places the capacitor or resistor on an anvil equipped with clamps which close down on the pigtails. Then the value of capacitance or resistance is measured, and a guide is set automatically so that the component drops down into one of several bins under the machine. One operator can check 10,000 to 12,000 units a day. Each bin corresponds to a predetermined percentage of tolerance. Fig. 2 shows the lower part of the electrical circuits by

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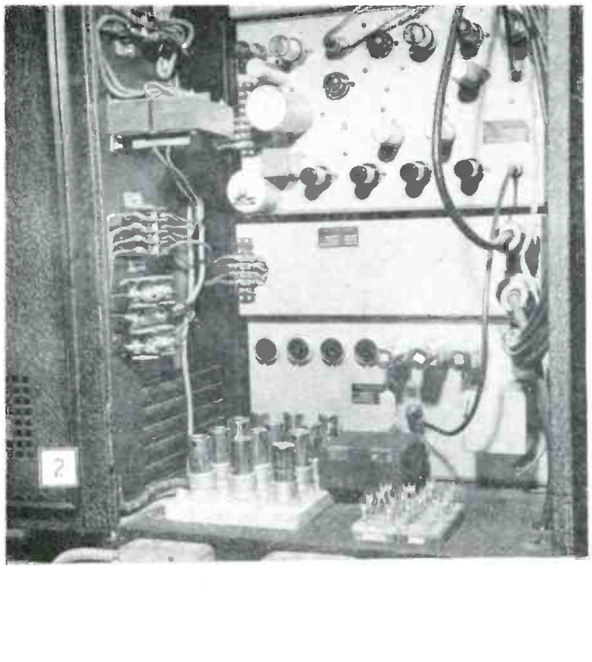
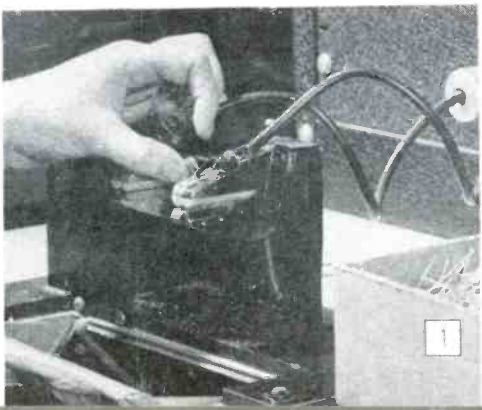
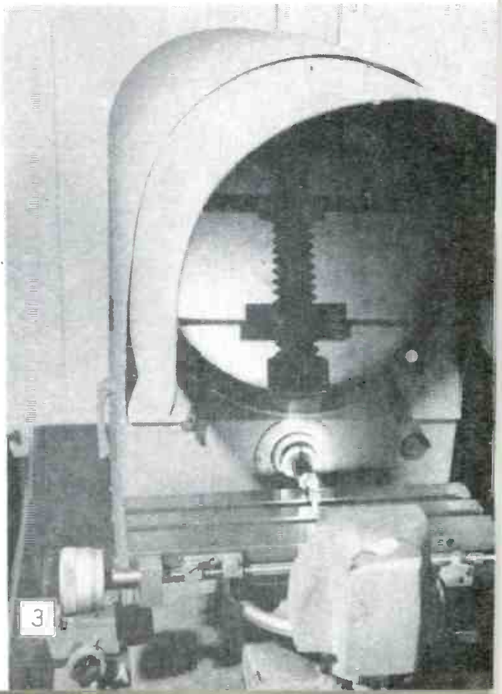


FIG. 1. BELOW: TEST BLOCK OF THE MACHINE THAT SORTS UP TO 12,000 RESISTORS OR CAPACITORS PER DAY, ACCORDING TO PER-CENT DEVIATION FROM A STANDARD VALUE

FIG. 2. PART OF THE CIRCUITS OF THE SORTING MACHINE. STANDARD VALUES OF CAPACITANCE AND INDUCTANCE CAN BE SEEN ON THE BOTTOM OF THE CABINET

FIG. 3. DIMENSIONS OF SMALL PARTS CAN BE CHECKED ACCURATELY BY EXAMINING THE ENLARGED SHADOW IN THIS COMPARATOR





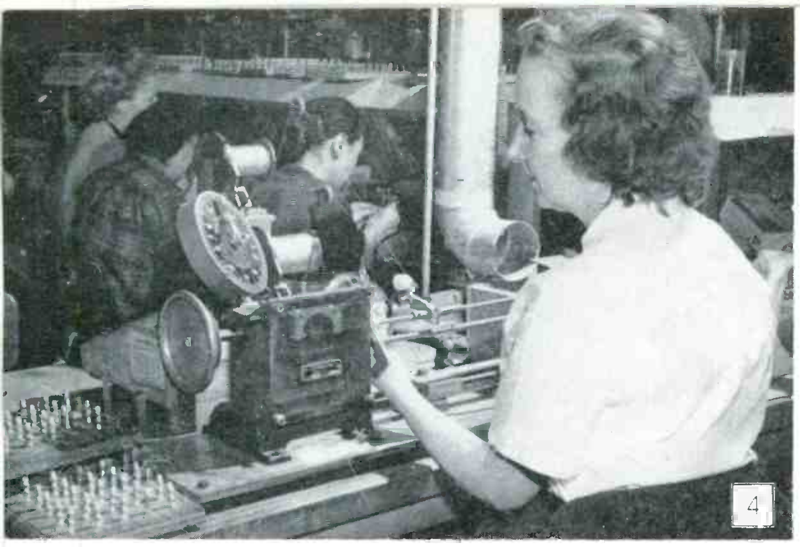


FIG. 4. WINDING COILS FOR DISCRIMINATORS. FIG. 8. CHECKING DRIFT AFTER HEATING IN OVEN, RIGHT, AND COOLING IN DRY ICE CHAMBER

which the selection is made. To set up the machine, it is only necessary to plug in the proper standards of capacitance or resistance, and the electrical circuits do the rest. Some of the plug-in units can be seen on the bottom shelf in Fig. 2.

Another important piece of inspection equipment is the Jones & Lamson bench comparator, Fig. 3. This is used for spot-checking

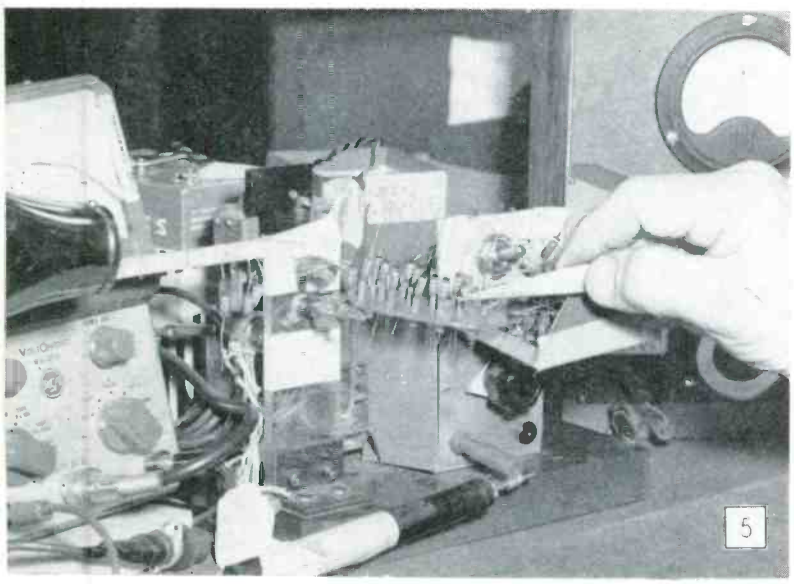


FIG. 5. THE DIODES, HEATED BY AIRSTREAM, ARE TESTED FOR MATCHING

screw machine parts by projecting a magnified shadow on the calibrated screen.

The greatest care and precision is required in the discriminator circuits of the receiver, Figs. 4 to 8. Temperature-compensating condensers are checked for drift at + 55° and −40°C. Diode crystals are checked and matched at 4.3 mc. with the same temperature range. In Fig. 5 a hot-air blower at the left is directed toward a group of diodes awaiting test. As the operator takes out one to measure it, he puts a new one in the air stream to be heated. Temperature is indicated by a thermocouple meter. Finally, the diodes are matched for voltage output within .5 volt at 4.3 mc.

The assembled discriminator, Fig. 6, is then sealed in a metal can with a soldered cover. This stage is illustrated in Fig. 7. The can is clamped in a water-cooled fixture during the soldering operation. This localizes the heat, so that the components are not affected. The completed units are given another check before they move on to the assembly line. Each one is heated in an oven, right in Fig. 8, for 1 hour at + 55° C., and then checked at 4.3 mc. Next, each is cooled for 1 hour in the dry-ice box at the left, and checked again. Permissible drift is ± 7 kc.

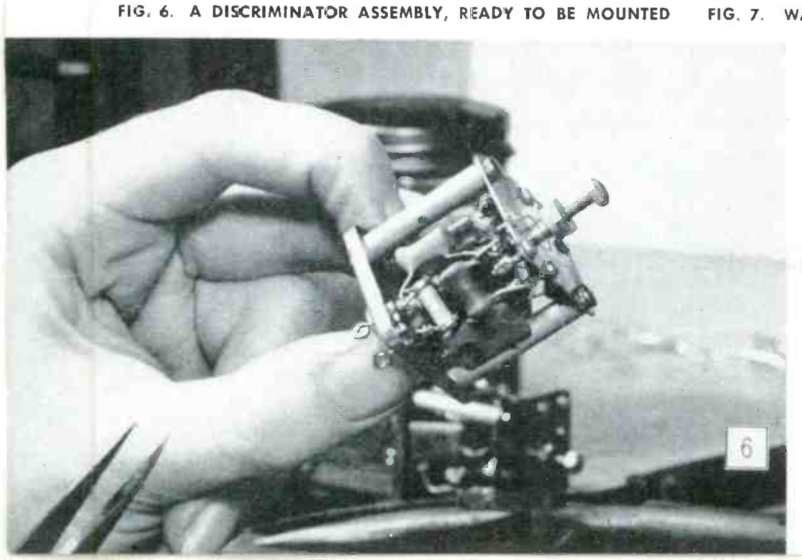
The alminum die casting for the chassis, Figs. 9, 11 and 13, is produced by the Aluminum Company of America. It has 36 cored holes, located to an accuracy of ± .002 in. In the final machining operation, these holes are threaded with a 2-56 tap. Each is checked in pre-assembly inspection, because defective threads in any hole would cause rejection of the chassis at any stage of assembly. This is done by a power-driven thread gauge, Fig. 9.

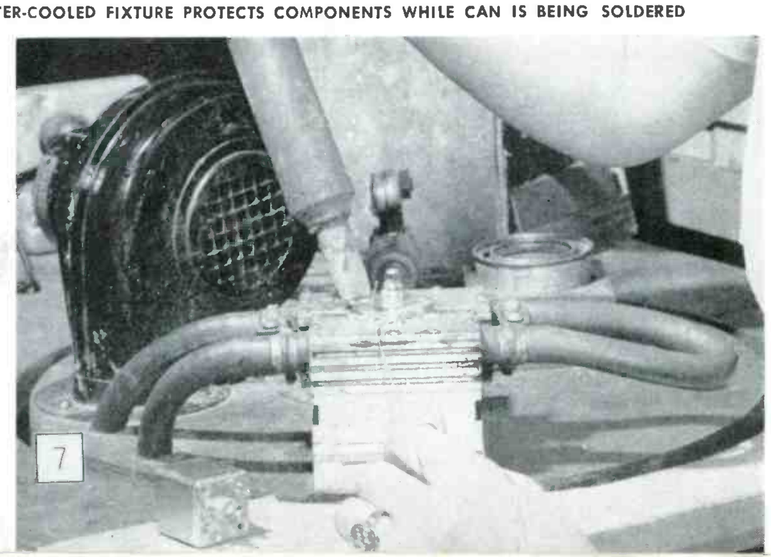
Chassis Assembly Techniques: The complete chassis consists of the main die-cast part and two auxiliary chassis formed of cold rolled steel, illustrated in Figs. 10 to 13. Figs. 10 and 12 show the sheet metal chassis as they are produced by Trifari, Krussman & Fishel. After forming, the barriers, which can be seen in Fig. 12, are spot welded in place. Then the chassis are hot-tin dipped. The appearance is more like plating, since the tin coating is only .0005 in. thick. That is because a centrifugal dipping process is used, a method developed originally in the manufacture of milk cans.

Next, to provide additional rigidity and electrical continuity, the barriers and corners are soldered by applying a paste of rosin and powdered solder with a brush, and the chassis are heated in an oxygen-free furnace. This eliminates oxidization, and the necessity of pickling. Only degreasing is required to remove the flux residue.

At this point, the Prokar tubular condensers are mounted on the

FIG. 6. A DISCRIMINATOR ASSEMBLY, READY TO BE MOUNTED FIG. 7. WATER-COOLED FIXTURE PROTECTS COMPONENTS WHILE CAN IS BEING SOLDERED





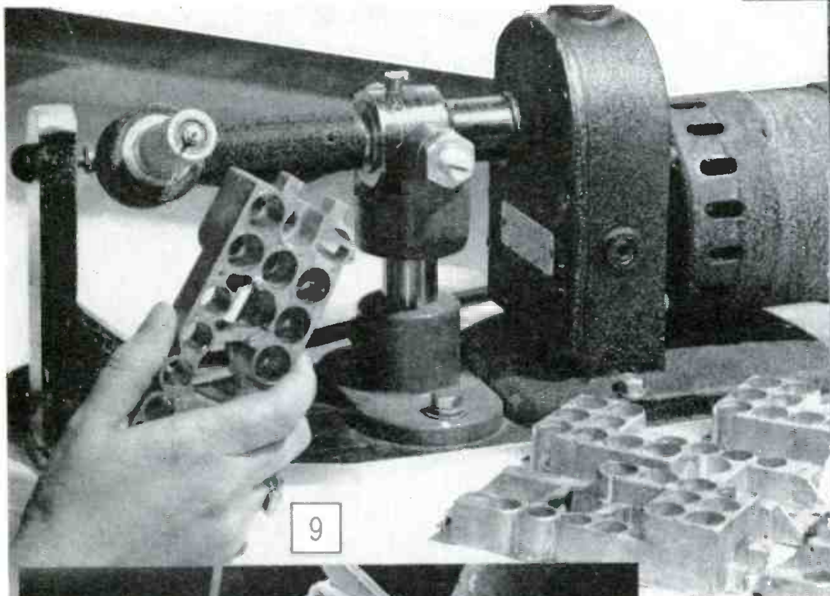
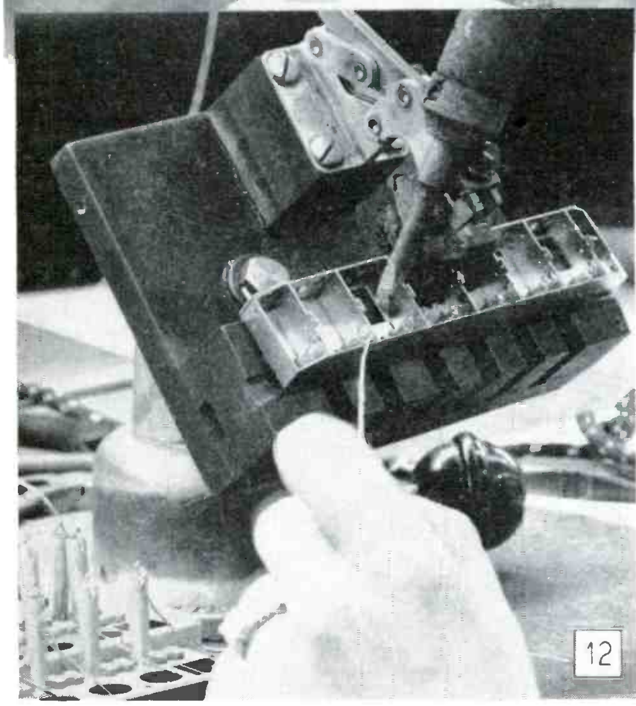
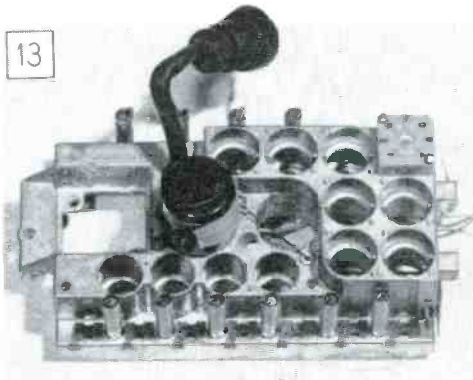


FIG. 9. POWER-DRIVEN THREAD GAUGE IS USED TO INSPECT EACH OF 36 THREADED HOLES. FIG. 10. SOCKETS ARE PRESSED INTO STEEL CHASSIS, ON WHICH TUBULAR CONDENSERS ARE ALREADY SOLDERED. FIG. 13. ASSEMBLY COMPRISES A DIE-CAST ALUMINUM CHASSIS, AND TWO CHASSIS FORMED OF SHEET STEEL





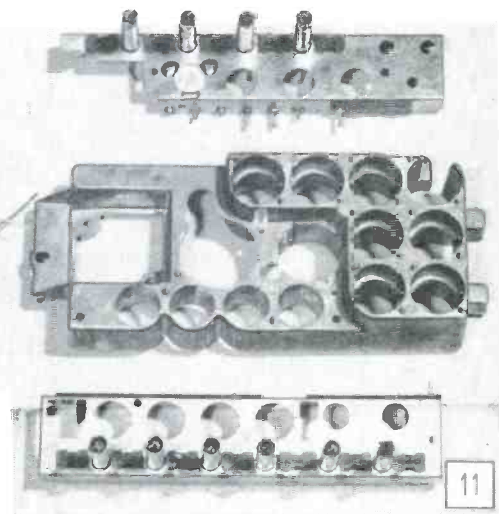


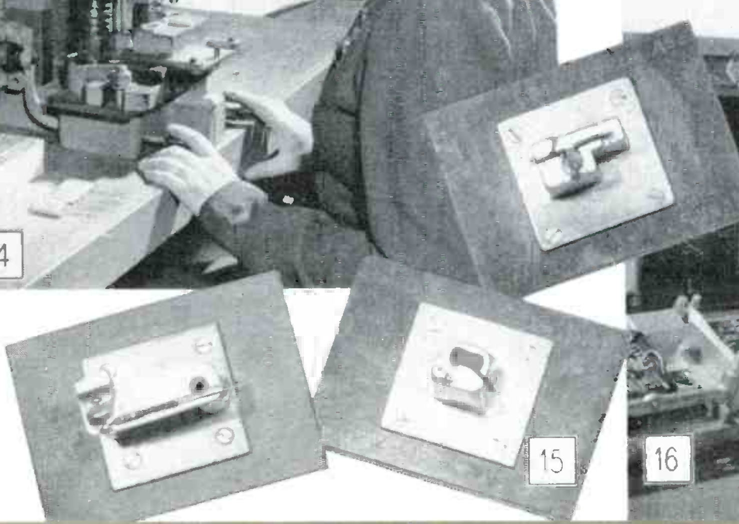
FIG. 11. THESE SECTIONS CARRY ALL TRANSMITTER AND RECEIVER COMPONENTS, YET THE ASSEMBLY IS SMALLER AND LIGHTER THAN THE BATTERY BOX

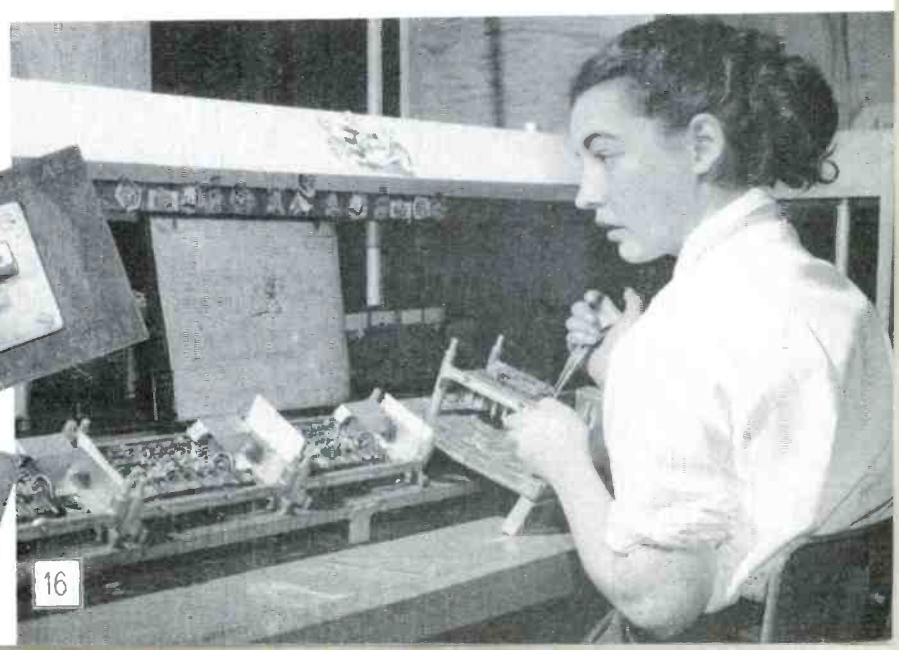
FIG. 12. SOLDERING GROUND WIRES FROM THE TUBE SOCKETS TO THE CHASSIS

FIG. 14. LEADS FROM THE SUBMINIATURE TUBES ARE LAID IN A SLOTTED FIXTURE, AND ARE CUT TO LENGTH IN THIS PNEUMATIC PRESS

FIG. 15. SOME OF THE FIXTURES USED TO FORM THE PIGTAILS OF CAPACITORS AND RESISTORS PRIOR TO DELIVERING THEM TO THE ASSEMBLY LINES

FIG. 16. EACH CHASSIS IS CLAMPED INTO A DIE-CAST CRADLE AT THE BEGINNING OF THE MAIN ASSEMBLY LINE, SO IT CAN BE PUSHED ALONG ON STEEL TRACKS. CRADLES HAVE CORNER POSTS DESIGNED TO PERMIT STACKING





chassis, as shown in Fig. 11. This calls for the skill of experienced jewelers. Flux is applied with a hypodermic needle. Then, using a gas torch and fine wire solder, heat is applied so quickly, and is so localized that the condenser cans are soldered in place without even melting the tin on the chassis. Experience has indicated this method to be superior to solder rings for this particular operation.

In Fig. 10, the operator is mounting the subminiature tube sockets, using a hand press. Next, the ground connections from the sockets are soldered to the chassis, as shown in Fig. 12. The leads from the tubes are cut to length in the pneumatic press illustrated in Fig. 14. Components are supplied to the assembly lines with the pigtails formed and cut to length. Fig. 15 shows some of the fixtures used.

As each chassis starts on the assembly line, it is mounted in a die-cast fixture, which can be seen in Figs. 16 and 18. The fixture also carries an inspection record card. The legs serve as guides so that the fixtures can be pushed along on steel tracks, Fig. 16. Also, as Fig. 18 shows, there are male and female posts at the four corners, so that the fixtures can be stacked.

In Fig. 18 are top and bottom views of the chassis, at the right with the tubes inserted, and at the left with the tube-clamping strips in place. The upper righthand view shows the RF and IF transformers inserted in the aluminum casting. The black can at the center contains the subminiature microphone and audio output transformers, with the discriminator next left. At the top right-hand corner is the test-point block, into which a meter can be plugged for checking the circuits.

The final assembly stage is represented at the left, where the covers and tuning-counters are in place on the adjustable slug-tuned RF and IF transformers, and the caps have been screwed on the discriminator adjustment. Purpose of the tuning-counters is to permit adjustment to various VHF operating frequencies. These wafer-thin, all-plastic devices are produced by Sobenite, Inc. of South Bend, and Brilhart Plastics of Mineola.

Before each chassis is given its final check, it is put on a shake-table, Fig. 17, to shake out odd bits of wire and solder. Then it is connected to a Roto-bridge, Fig. 19, which checks the circuits at 83 points, one after another. This device, manufactured by Industrial Instruments, Inc., at Jersey City, indicates the location of any defective components, or any fault in the wiring.


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FIG. 17. AT END OF ASSEMBLY LINE, EACH CHASSIS IS RUN ON SHAKE-TABLE

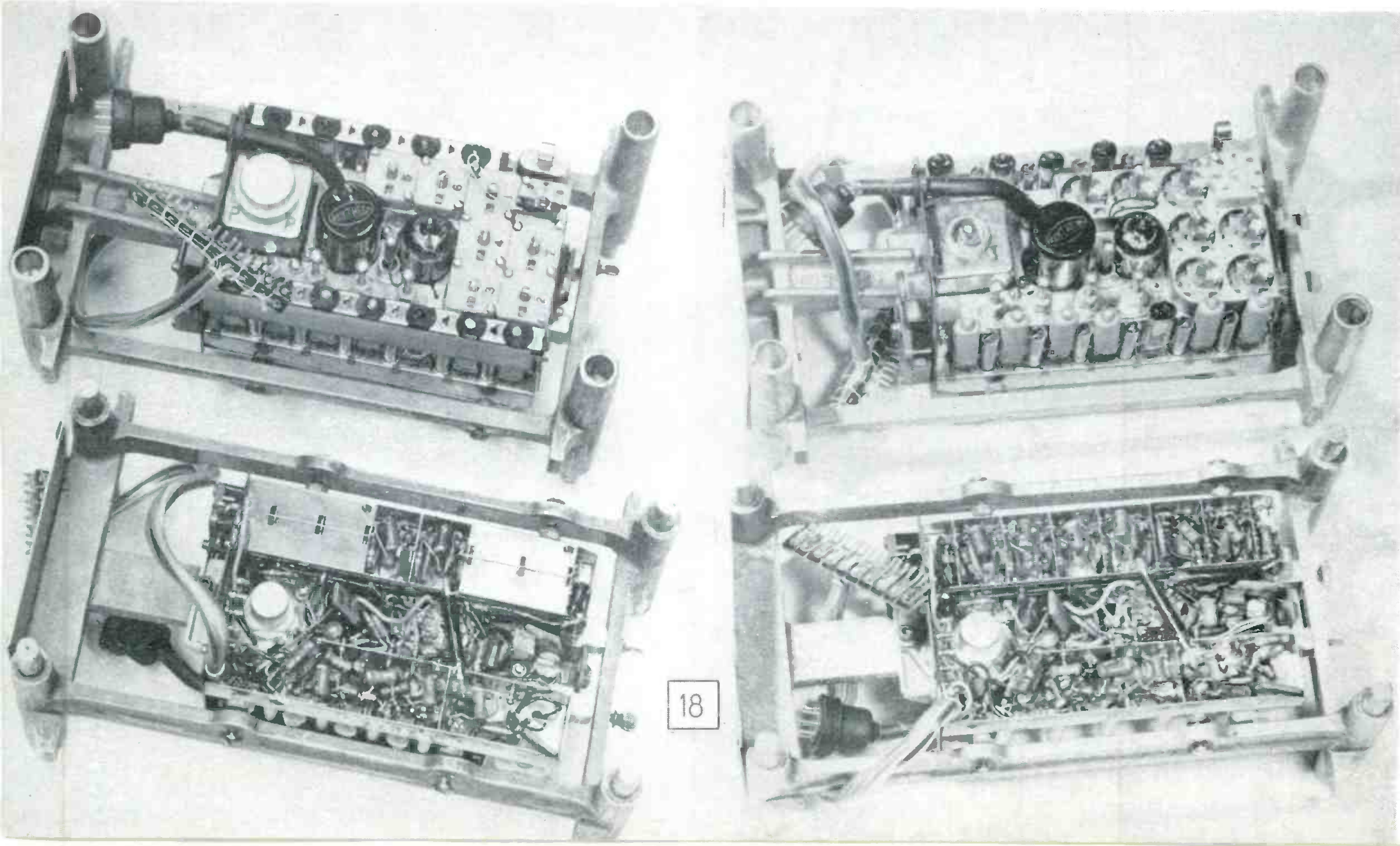
While the PRC-6 is small in size, the transmitter-receiver chassis occupies only a small part of the case. The chassis can hardly be seen in Fig. 20, where it is being fastened to one half of the die-cast magnesium case.

Final Inspection: After each PRC-6 has gone through all the conventional electrical tests, a threaded cap is removed from the lower end of the case, and an air hose carrying $3\frac{1}{2}$ lbs. pressure is screwed on. This can be seen in the illustration at the top of page 21. When the entire unit is plunged into a tank of water, if any air bubbles rise, the unit is rejected.

Mountings of the microphone and receiver are water-tight but the openings through the case are further protected by polyethylene membranes which we call spit-catchers. Their purpose is to protect the microphone and receiver from condensation in cold weather. If ice forms on the polyethylene, it can be broken off with a tap of the finger.

Out of every 100 PRC-6's, complete measurements are made on 15 in the test room shown in Fig. 21, and then put through the Bowser cold chamber, Fig. 22. If a single unit should fail to pass,

FIG. 18. TOP AND BOTTOM VIEWS OF THE CHASSIS, AT TWO STAGES OF ASSEMBLY. NOTE TUBE LINEUP AT RIGHT, AND THE TUBE CLAMPS IN PLACE, LEFT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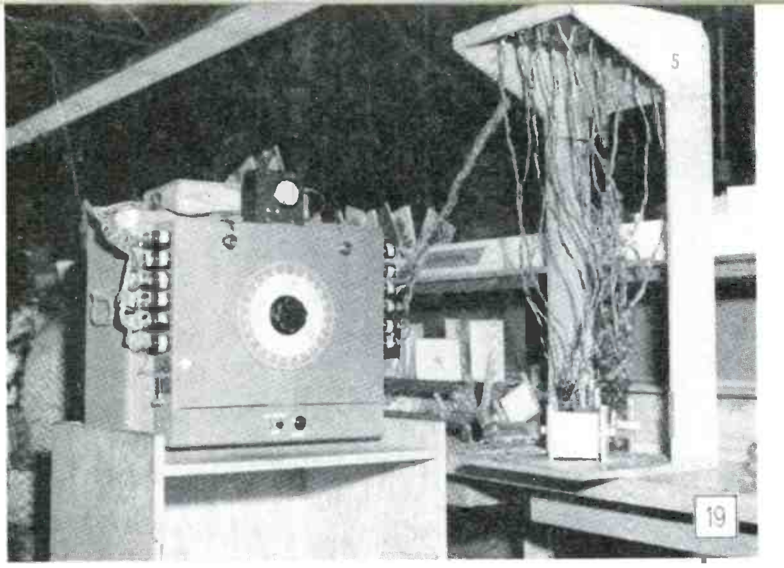


FIG. 19. THIS ROTO-BRIDGE CAN LOCATE AN ERROR AT ANY OF 83 POINTS IN THE CIRCUIT

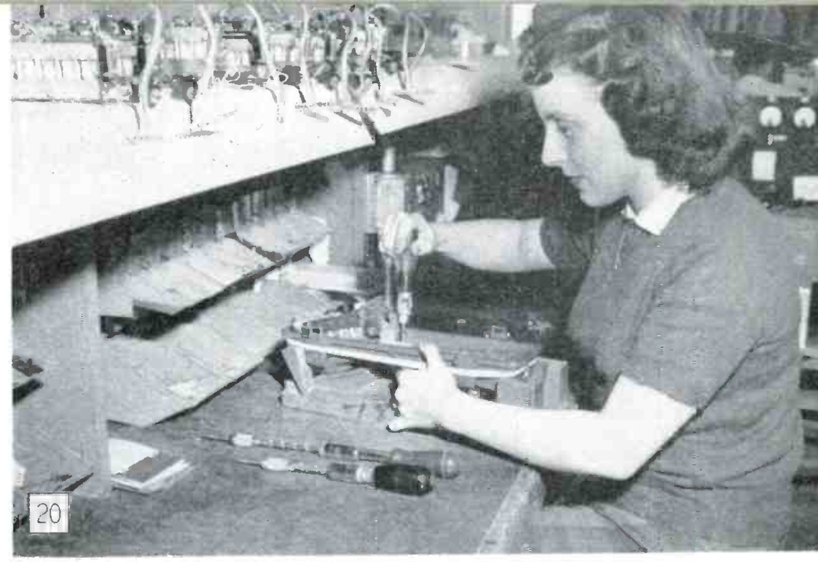
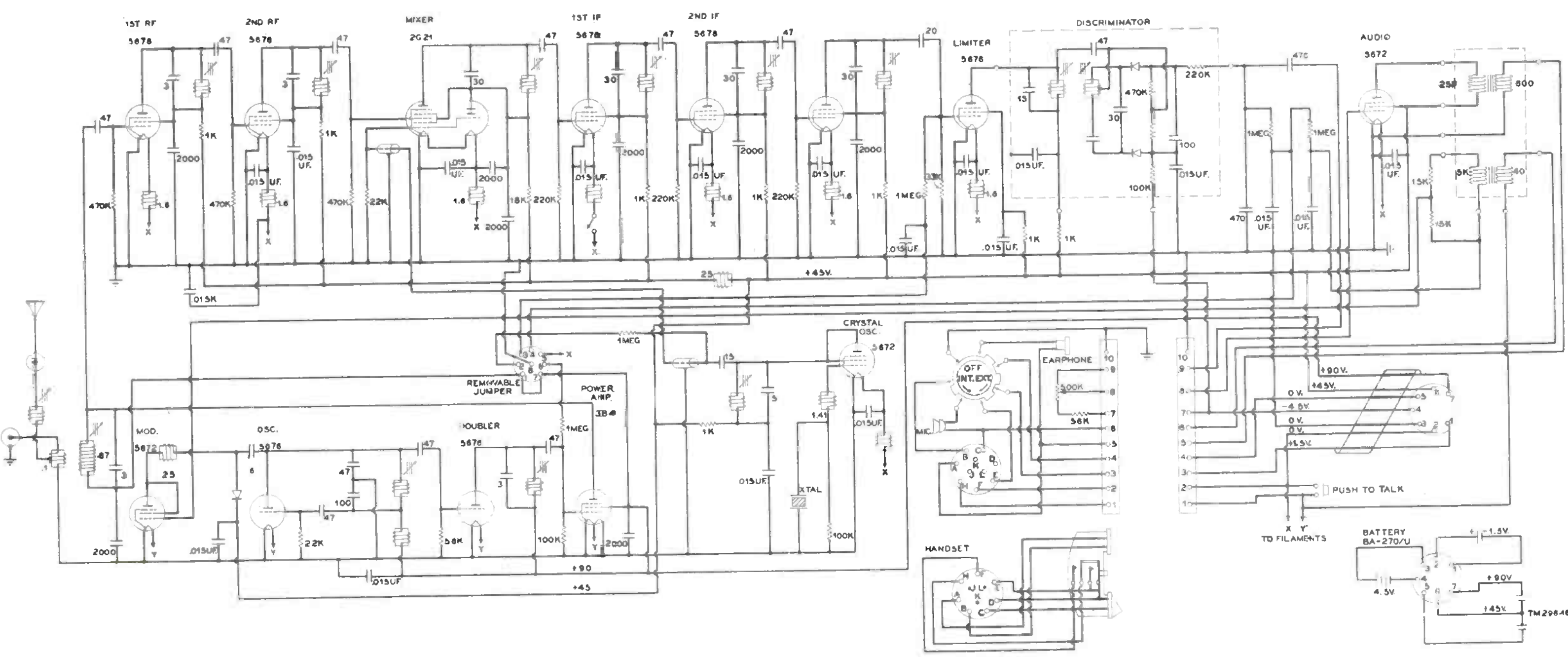


FIG. 20. MOUNTING THE CHASSIS IN THE PRC-6 CASE

each of the 100 is then tested. That rarely happens because of the unusual efficiency of this manufacturing operation. To support the excellent teamwork in our factory departments, we have established a highly-organized system of quality control. This not only contributes to establishing minimum costs, but also, and of greater importance, insures that every unit shipped will operate satisfactorily in the field. As examples of the success of this quality control, it may be mentioned that approximately 50,000 soldered joints are made daily in PRC-6 production, with an average of 40 rejects. Of about 10,000 electrical checks, the rejections average around 60 per day.

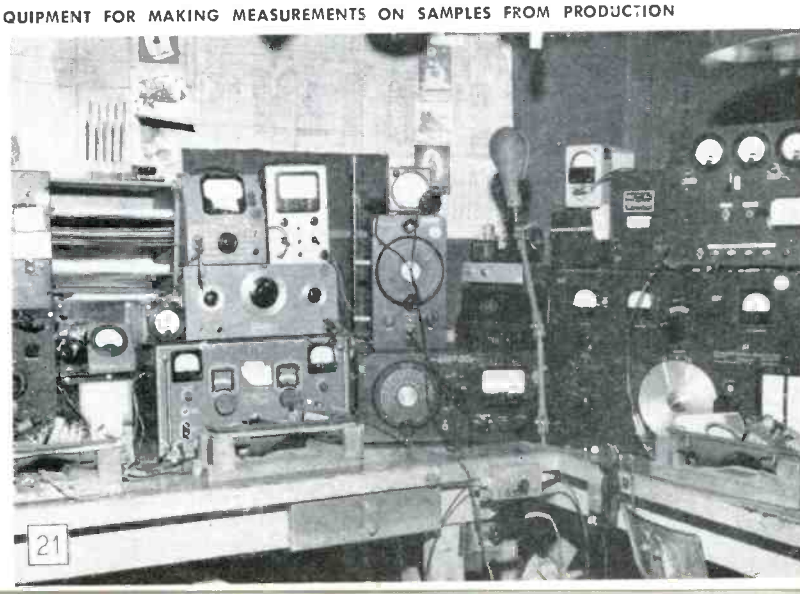
Of course, these photographs and the description only high-spot the various stages in the manufacture of the PRC-6. The experience gained from this operation has been made available to other suppliers of this equipment to the Signal Corps, as one contribution of many that Raytheon has made to the defense effort since the outbreak of the Korean war. We believe that these ideas can also be adapted to the design and production of civilian communication and television equipment.

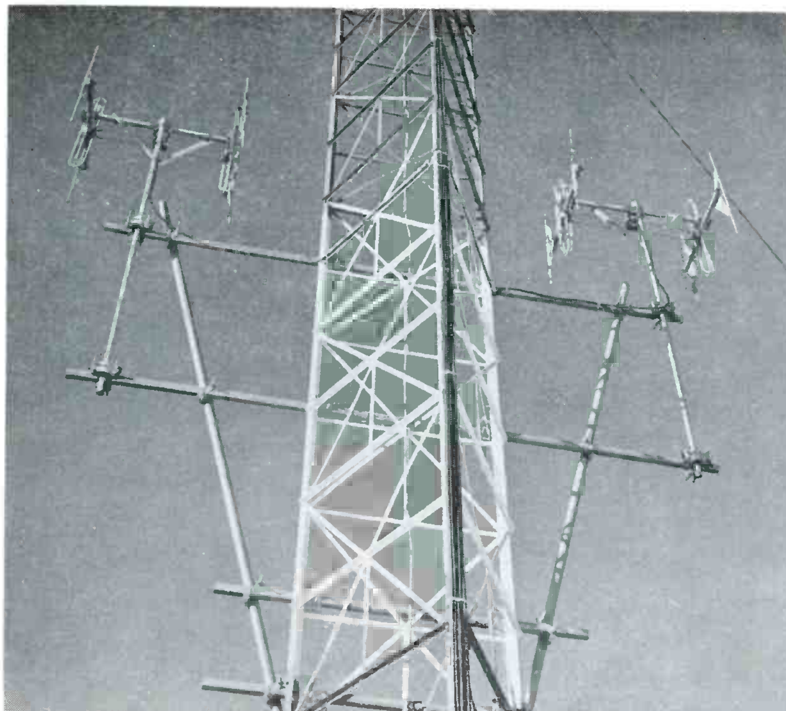


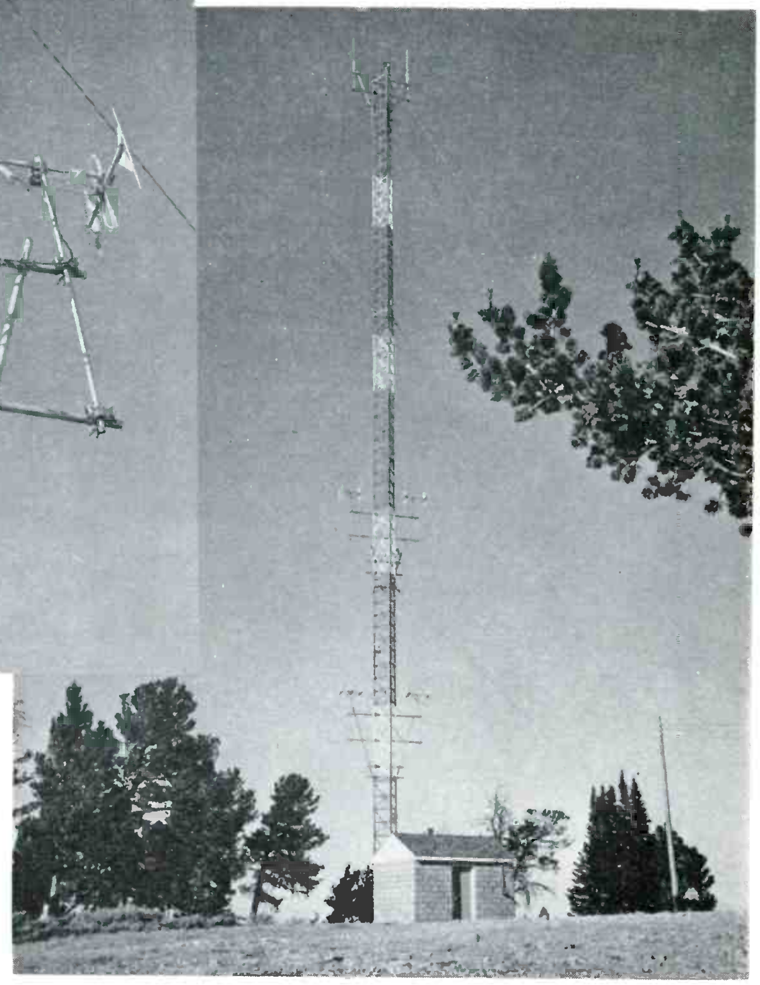
THIS SCHEMATIC OF THE PRC-6 SHOWS THE TEST SOCKETS, DISCRIMINATOR ASSEMBLY, HANDSET SWITCH AND PLUG, AND BATTERY CONNECTIONS

FIG. 22. COLD-CHAMBER TESTS ARE MADE ON SAMPLING BASIS

FIG. 21. EQUIPMENT FOR MAKING MEASUREMENTS ON SAMPLES FROM PRODUCTION







AT CASPER MOUNTAIN, THE TWO ANDREW GROUND PLANE ANTENNAS ARE FOR COMMUNICATION WITH HIGHWAY PATROL AND HIGHWAY MAINTENANCE VEHICLES, ON 42.82 AND 47.22 MC., RESPECTIVELY. THE LOWER DIRECTIONAL ANTENNAS ARE FOR TRANSMITTERS AND RECEIVERS OPERATING WITH CONTROL POINTS AT POLICE HEADQUARTERS AND THE STATE MAINTENANCE SHOP, LOCATED IN THE CITY OF CASPER

How Wyoming Uses Radio Communication

HIGHWAY DEPARTMENT EMPLOYS UNIQUE SYSTEM ENGINEERING TO MEET UNUSUAL REQUIREMENTS — *By* THURMAN D. SHERARD and JOHN T. ROBERTS*

SOME idea of the operational problems which were met in planning the new radio system installed in 1952 by the Wyoming Highway Department can be gained by considering that the area involved is more than half again the total of the six New England states.[1] Although the population is one third that of Rhode Island, our 5,500 miles of state highways carry a heavy load of traffic. Ranches, farms, oil wells, and mines are largely dependent on trucks for transportation. Distances between centers of population are great, and our people are accustomed to making long trips. It is not unusual for them to travel 200 miles to a basketball game, and to return the same night. And vacationists come to this state in great numbers, adding substantially to our traffic.

In Wyoming, the Highway Department is not only responsible for construction and maintenance, but also for performing the functions of a state police organization in enforcing highway laws, checking the ton-mileage of trucks, and protecting life and property on the roads.

Both the maintenance and patrol functions are complicated by the terrain, which combines wide plains and rugged mountains, and extremes of high and low temperature, subject to swift changes which may bring icing conditions or heavy snow.

Planning the New System: As a preliminary to setting up our new system, we sent questionnaires to the Highway Departments of the 47 other states, asking for 14 points of information ranging from the type of equipment used to methods of financing and control. Answers were received from 45 states, many giving us extensive and very helpful data. We were fortunate in being able to plan a completely new FM system to replace the 1.642-mc. AM equipment installed prior to 1940. Thus we were free to take advantage of the newest developments to meet our present needs, and capable of handling such future requirements as we could anticipate.

It was decided to use one frequency, 47.22 mc., for the Highway Maintenance cars and base stations, and a second frequency, 42.82 mc., for Highway Patrol cars and base stations. A subsequent decision to provide for cross-channel communication resulted in our specifying an unusual design for the mobile units. That is, most of the units have two transmitters, on 47.22 and 42.82 mc., and one receiver, contained in a single metal case.

Under this arrangement, a Patrol car, normally communicating on 42.82 mc., can switch to 47.22 mc. if he wants to call

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[1]Wyoming covers 97,500 miles, compared to 62,900 for the New England states. The population is 290,500, while Rhode Island, of 1,067 square miles, has a population of 791,900.

a Maintenance car. On picking up such a call, the operator in the Maintenance car switches his transmitter, normally on 47.22 mc., to 42.82 mc. With a frequency separation of 4.40 mc., there is adequate protection against desensitization under all conditions. Cross-channel communication is proving to be

ADMINISTRATIVE ASSISTANT THURMAN SHERARD, RIGHT, AND CHIEF RADIO TECHNICIAN JOHN ROBERTS REPORT TO J. R. BROMLEY, SUPERINTENDENT OF THE WYOMING STATE HIGHWAY DEPARTMENT

of great value, particularly in winter weather, when Patrol cars and Maintenance vehicles must work together.

The great distances between population centers make it important to tie in the county sheriffs' offices and the city police. Accordingly, it was decided that the State should purchase and maintain mobile equipment for local law enforcement agencies at a monthly charge of $25.00 per unit except at dispatch stations, where the equipment should be supplied and maintained by the State without charge, in return for operation service. The frequency of 161.73 was selected for local police, and the Patrol frequency of 42.82 for the sheriffs.

Finally, to provide circuits between control points and the main transmitters. 157.05 and 161.43 mc. were selected for Highway Maintenance, and 156.75 and 161.61 mc. for the Highway Patrol.

Location of Transmitters: At the time our new communication project was started, it was generally considered necessary to select line-of-sight transmitter locations. On that basis, the topographic maps showed only a few suitable sites for the main stations, and those were on the higher peaks where there were no access roads. To use those locations meant installing miles of power lines, and building new roads. Engine-driven generators would be needed for emergency power, and it would be necessary to transport fuel to the mountain tops. If a breakdown occurred, there might be serious delays during winter months when the equipment would be needed most.

So we abandoned accepted methods, and went off on our own. Instead of picking high points first, and trying to lay out power lines and roads, we decided in what areas the main stations should be located. Then we consulted the resident maintenance employee, engineer, or patrolman in each area to get advice as to a high point adjacent to a power line, and accessible by car.

LEFT: ALPRODCO TOWERS ARE USED AT THE SHOPS AND OTHER REMOTE CONTROL POINTS

Next, with the cooperation of manufacturers who loaned us the necessary transmitters and receivers, we made tests at each location. To keep our results on the conservative side, we put up a 40-ft. tower, for example, where we planned to use a 100-ft. tower, and we used 60-watt fixed transmitters instead of the 250-watt installations projected.

After the test equipment was set up, we drove three or four cars over every mile of highway in the area to be served from that point, giving particular attention to stretches running through canyons or over low sections. Continuous communication was maintained, and logs were kept to show the time. text of the messages, and quality of the signals.

Less than half a dozen of the points we selected proved to be unsuitable, and those gave us enough information so that, on the next try, we found a satisfactory location in each case. It was immediately apparent that we were not limited to line of sight. In several instances, we were able to talk between points at elevations of 5,000 ft. despite intervening mountains 10,000 to 12,000 ft. high. And in canyon roads where we did not expect to pick up any signals, the radio waves seemed to travel as if the high walls acted as wave guides.

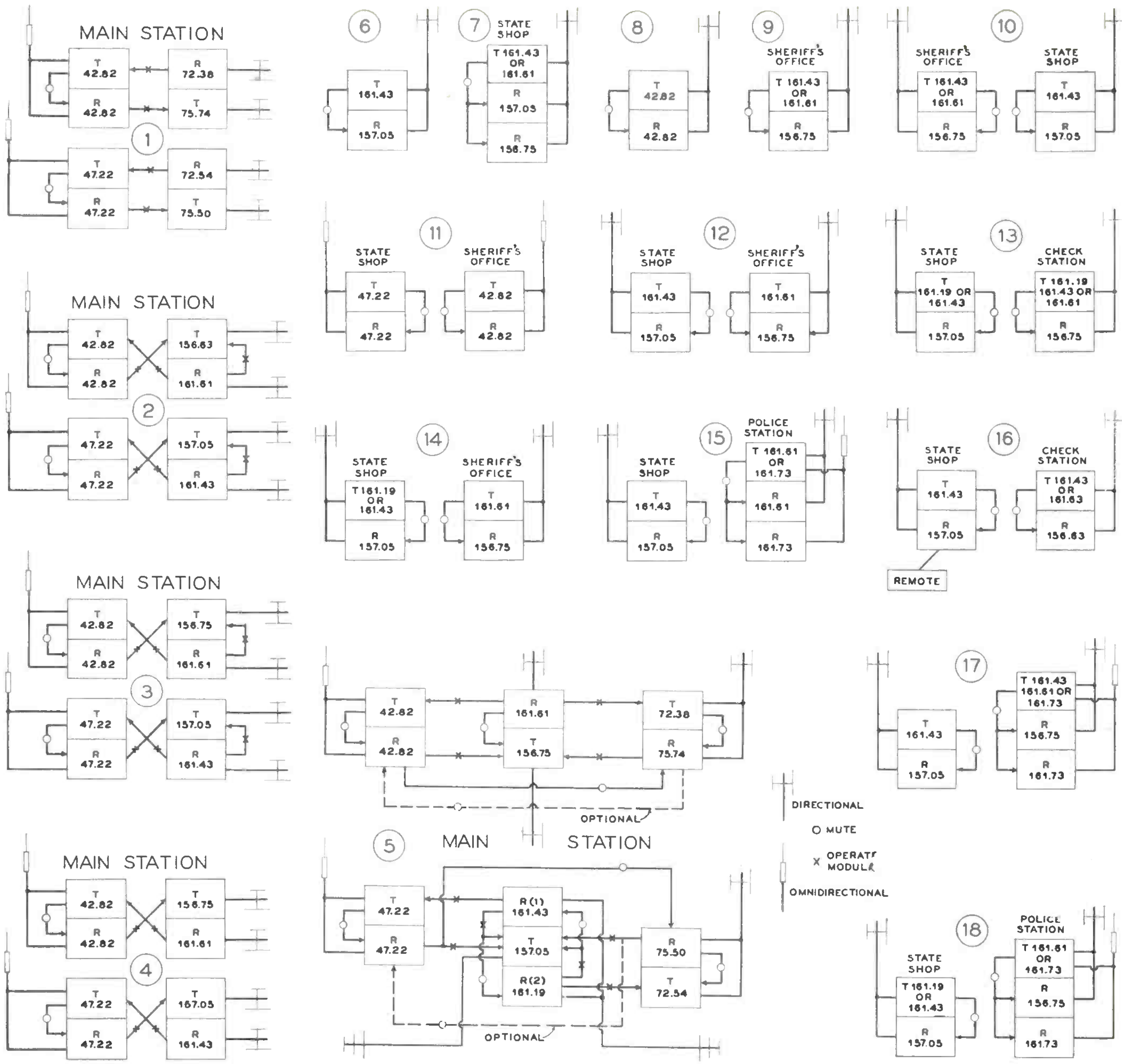
The cost of this work was about $8,000. Judging from the experiences of other States, we estimate that this probably effected a saving of $50,000 because of the modest expense involved in the method we employed, and because we avoided the necessity of relocating any of our transmitters after they were installed.

Specifications for Equipment: Our system planning and transmitter survey were carried out together and, as that part of the work progressed, we developed our specifications. We

THIS TYPE OF MOTOROLA CONSOLE IS USED AT REMOTE CONTROL POINTS

decided on 100-ft. towers for the main 250-watt transmitters except at Casper Mountain, which required a 150-ft. tower, all designed for wind loads up to 80 mph., with a ½ in. coating of ice. One of the accompanying illustrations shows the Casper Mountain station, with a detailed view of the directional antennas. These are arranged so that the full sensitivity of the receivers is available when the transmitters on other frequencies are operating at full power. Although we intended originally to use 60-watt mobile transmitters, we came to the final conclusion that 30-watt units would be adequate.

The specifications called for equipment capable of operating at high altitudes. Components may be entirely satisfactory at sea-level, yet fail at 5,000 to 10,000 ft. That is an impor-

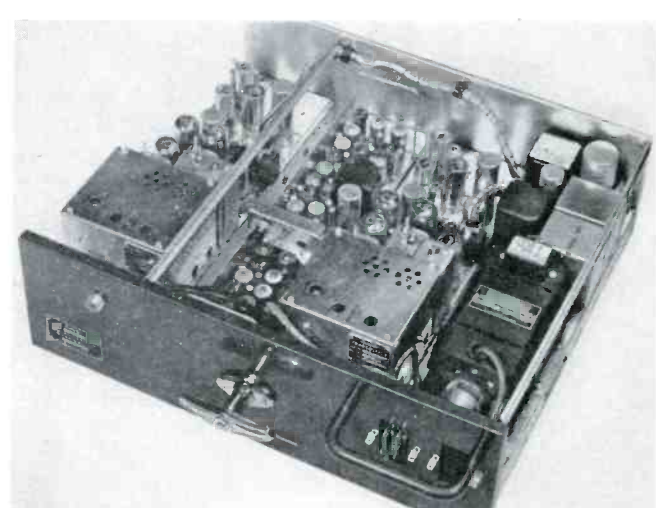


BLOCK DIAGRAMS OF THE VARIOUS TYPES OF INSTALLATIONS WHICH COMPRISE THE WYOMING STATE HIGHWAY DEPARTMENT'S RADIO SYSTEM

tant consideration in Wyoming, for such a large part of the area lies between those levels. Electrical specifications were made extremely rigid — so much so, in fact, that none of the manufacturers could meet them without making modifications in their standard equipment. However, our plan of deciding what we wanted, and then letting the manufacturers figure out ways to meet our needs, has already paid dividends in high performance and low maintenance.

This was a turn-key project, in which the contractor was required to supply all equipment, materials, engineering and labor involved in the construction of 10 transmitter houses, erection of towers, and the installation of the fixed and mobile equipment. Bidders were permitted to specify exact frequencies in the 72 to 76-mc. and 152 to 162-mc. bands, with the provision that they must be licensable by the State. Recognizing that much of the engineering details would be worked out by the bidders, and that their solutions to problems might vary widely, the State reserved the right to award the contract to the bidder offering the best solutions as determined by the State, and not necessarily to the lowest bidder.

The contract was finally awarded to Motorola, Inc., for



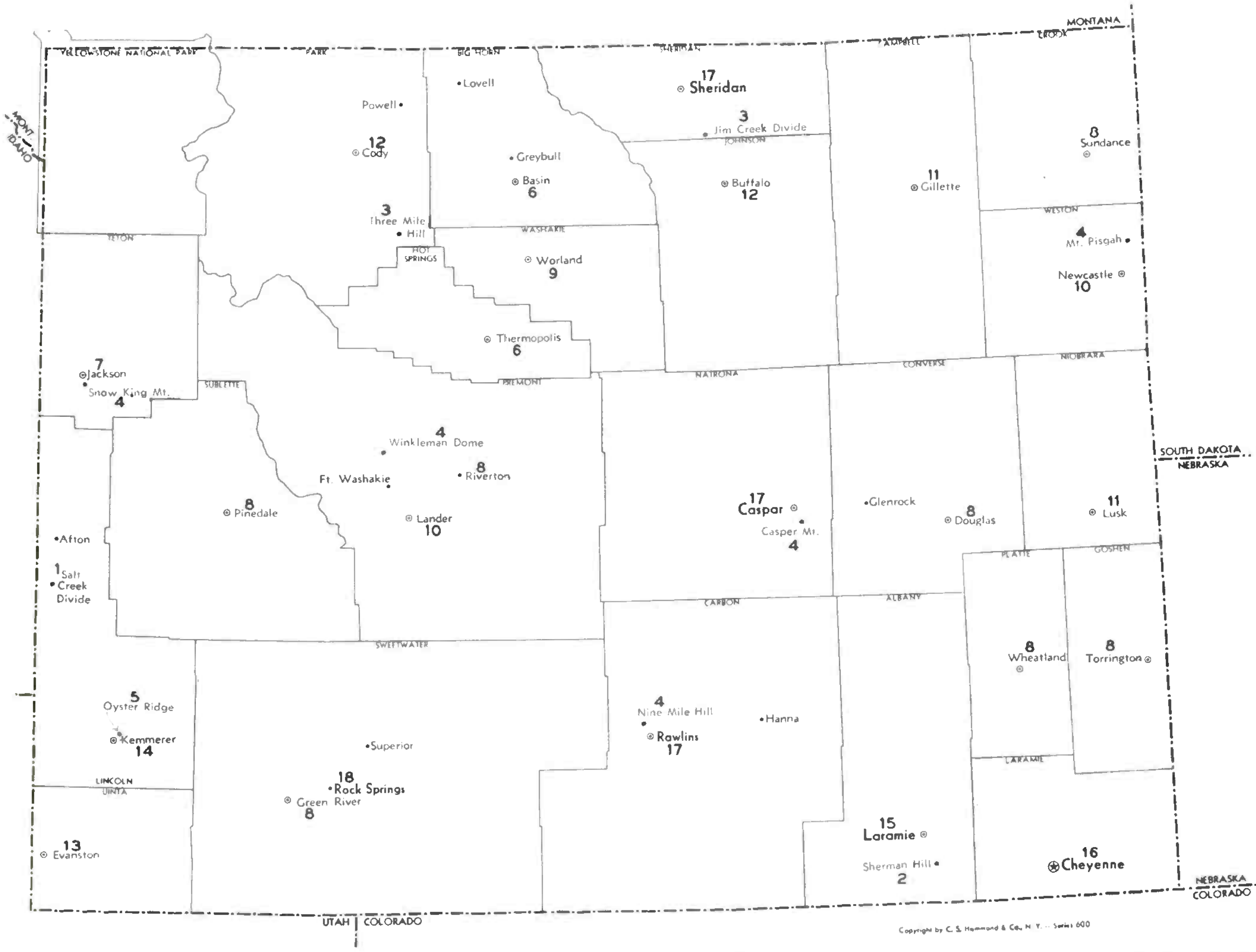
SPECIAL MOTOROLA MOBILE UNITS HAVE TWO 30-WATT TRANSMITTERS WITH ONE POWER SUPPLY AND A RECEIVER MOUNTED IN A SINGLE CASE

$279,768 which, as it turned out, was the low bid. Subsequently, and before the installation was completed, a further sum was made available for additional facilities.

System Engineering Plan: The accompanying map and the block diagrams show the location of the main transmitters, remote control points, and associated installations operated by sheriffs and local police departments. In all cases, radio links rather than wire lines were provided between the control points and the main stations.

The plan of locating the transmitters follows the pattern of the State highways, as they define the activities of both the Maintenance and Patrol Departments. However, the conditions are such in Wyoming that communication is possible over exceptionally long distances, so that we are getting practically state-wide coverage.

Tying in Sheriff's Offices and local police departments under our plan of leasing and maintaining State-owned equipment has proved to be a highly effective way of extending the coverage of our system, and obtaining coordinated action in matters



MAIN STATIONS AND ASSOCIATED OPERATING POINTS. NUMBERS ON THIS MAP CORRESPOND TO THOSE SHOWN ON THE BLOCK DIAGRAMS OPPOSITE

The diagrams of the different installations show the interconnections between receivers and the transmitters and the different operating frequencies, whereby receivers are either muted or used to pick up signals which then modulate associated transmitters operating on other frequencies. Numbers on the map indicate the corresponding block diagram for the equipment installed, and the method of operation can be traced by the frequencies indicated.

An explanation of one special situation will help to clarify the system of operation. Four frequencies in the 72-mc. range are used for repeater circuits between Salt Creek, No. 1, and Oyster Ridge, No. 5. When Patrol signals are picked up at Salt Creek on 42.82 mc., they are fed to the 75.74-mc. transmitter and are picked up by a receiver at Oyster Ridge. This feeds the 156.75-mc. transmitter which has an antenna beamed to the Sheriff's Office at Kemmerer, No. 14. Also, calls picked up at Oyster Ridge on 42.82-mc. are beamed to Kemmerer on the same transmitter. In a similar way, calls on the maintenance frequency of 47.27 mc. picked up at Salt Creek reach the State Shop at Kemmerer via Oyster Ridge.

of law enforcement and in protecting life and property on the highways.

Additional Communication Services: By the time this account appears in print, further modifications may have been made to broaden the usefulness of our radio system. We gave the most careful consideration in our initial planning to the matter of future expansion. We hope to include the engineering and construction departments on our Maintenance frequency, and our Patrol frequency may be made available to the Game and Fish Commission, and to the Civil Defense Agency. Arrangements have been made already to allow pilots to file flight plans over our network wherever CAA facilities are not available to them. Plans for additional public services are being considered as a result of the new experiences in the course of operating our system. Although we are using only two frequencies for the Highway Departments' main stations and mobile transmitters, with 40-kc. modulation, our equipment was all designed so that, at very small cost, it can be altered for 20-kc. operation.

Important Considerations for the

Selection of a Relaying System

CHARACTERISTICS OF DIRECTIONAL AND PHASE COMPARISON RELAYING SYSTEMS, AND THEIR APPLICATIONS — *By* R. C. CHEEK AND J. L. BLACKBURN*

SINCE the introduction of the distance-type carrier relaying system about 15 years ago,[1] carrier pilot relaying has become the standard method of protection for important overhead transmission lines of more than a few miles in length. The more recent introduction of the phase-comparison relay system[2] gave further impetus to carrier relaying. No other type of protection generally provides instantaneous and simultaneous tripping of widely separated terminal circuit breakers for all types of faults and all fault locations within the protected zone. Such high-speed isolation of the fault area contributes greatly to increased continuity of service by minimizing fault damage, reducing outage time, and generally improving system stability.

Basic System Operation: The standard power directional comparison carrier systems have been built around three-zone distance-type relays, although other types of fault detectors have been used in special cases. A typical directional comparison carrier relaying system, using type HZ impedance relays, is shown in Figs. 1, 2, and 3. The direction of power flow under fault conditions is examined by the relays at each terminal. If fault power is flowing into the line at all terminals, then each set of relays trips its associated breaker. However, if fault power flows out at any terminal, an external fault is indicated, and the relays at this terminal transmit a blocking indication to all the other terminals in order to prevent them from tripping. In this system, the carrier need be on only during an external fault, at which time a continuous blocking signal is transmitted.

*Westinghouse Electric Corp., Baltimore, Maryland and Newark, N. J., respectively. A paper given at the 1952 Winter General Meeting of the AIEE.

[1] "A New High-Speed Distance-Type Carrier Pilot Relay System" by E. L. Harder, B. E. Lenehan, and S. L. Goldsborough, *AIEE Transactions*, Vol. 57, No. 1, January 1938, pp. 5-10.

[2] "A New Carrier Relaying System," by T. R. Halman, S. L. Goldsborough, H. W. Lesner, and A. F. Drompp, *AIEE Transactions*, Vol. 63, No. 3, March 1944, pp. 97-99.

In the phase comparison carrier system, the phase angles of the currents at the line terminals are compared. The type HKB system, shown in Figs. 4 and 5, is a typical phase-comparison system. A sequence filter fed by three-phase currents provides a single-phase output voltage proportional to various combinations of phase A positive, negative, and zero-sequence current components. This voltage is used to operate the fault detector and to control the carrier (carrier). Phase-angle comparison is accomplished by transmitting carrier during alternate half-cycles of the voltage wave and comparing the time positions of the local and remote half-cycle blocks of carrier in an electrical circuit. On an internal fault, with all currents entering the protected line, the blocks of carrier are essentially in phase. This permits operating current to flow in the relay during the half cycles when no carrier is on, thereby causing it to trip the breakers. On external faults, the blocks of local and remote carrier at each terminal are out of phase and provide restraining voltage over the complete cycle. Therefore, in this scheme, alternate half-cycle blocks of carrier must be transmitted by all terminals for both internal and external faults.

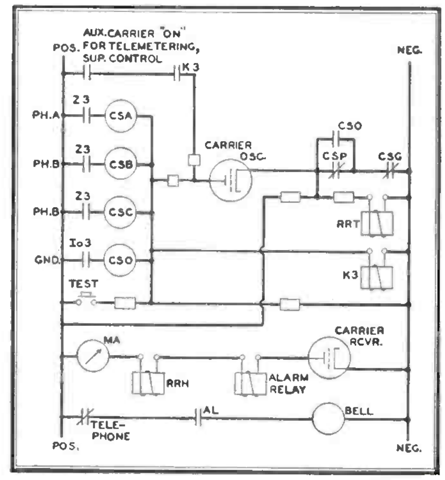


FIG. 2. CONTROL CIRCUITS, DIRECTIONAL SYSTEM

With two distinct basic types of carrier relaying systems available, the relay engineer is confronted with the necessity for making a choice between them for any given application. It is the purpose of this paper to discuss the relative advantages and limitations of each system, and to point out certain factors that have a bearing on the choice of a carrier relaying system for any specific application. Particular attention is given the problems associated with the protection of multi-terminal lines.

Since the channel requirements are essentially the same for either type of carrier relaying system, these problems will not be considered here. Both systems were developed for use with carrier-frequency energy superimposed on the transmission line being protected. They are readily adaptable, however, to other types of transmission media such as pilot wires or microwave systems. Microwave channels which handle relaying as well as other functions now are being set up in several areas. Thus, a new field for carrier-type relay protection has been

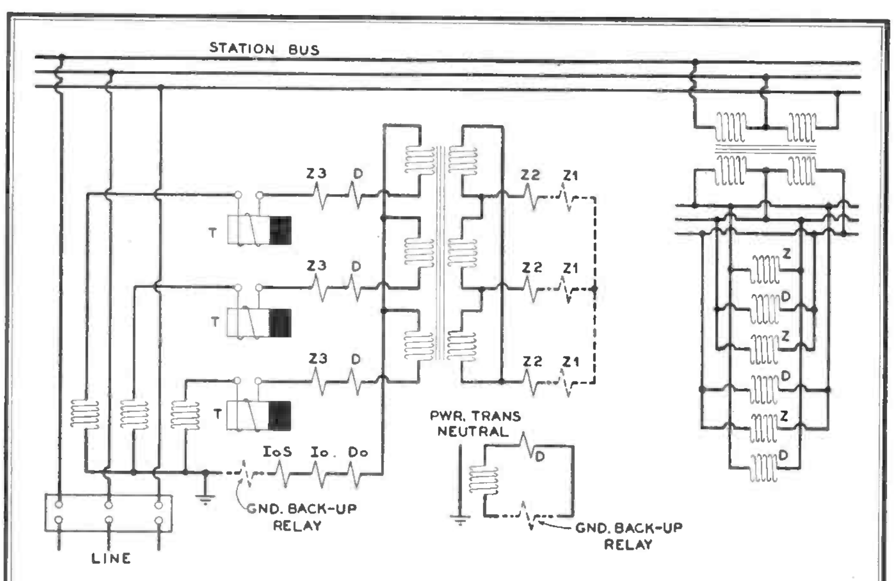


FIG. 1. THE BASIC AC CIRCUITS FOR A DIRECTIONAL-COMPARISON CARRIER RELAYING INSTALLATION

opened, and there is promise of considerable activity.[3]

Relative Advantages:

The degree of complexity of the two relaying systems is about equal, contrary to general belief. On the surface, the directional comparison scheme appears more complicated, but this is because the back-up elements are combined with the carrier elements. Disregarding back-up elements, directional comparison involves more mechanical parts and contacts and fewer electrical circuits, while the phase comparison system requires fewer mechanical elements and contacts, and more electrical circuits. The choice of systems on this score alone is largely a matter of whether one prefers electrical or mechanical circuits. On the basis of equivalent back-up protection, the two systems occupy approximately the same amount of switchboard space.

The absence of inherent back-up protection in the phase comparison scheme is an advantage in applications where the carrier system is used to supplement existing slower-speed relays. There is merit in having two independent relay systems, with the phase comparison carrier system as the first line of protection and another system for back-up. The two systems can be operated from different sets of current transformers, if desired. In many of these cases, distance-type relays are used for back-up protection.

A major advantage of the phase comparison system is that no potential transformers or potential devices are required for its operation. This advantage is nullified to a large extent if potential sources are already available or the back-up system requires potential sources. Distance-type relays, whether used in the directional comparison carrier scheme or for back-up protection, require a source of three-phase potential on the protected line or the associated bus. The impedance or reactance to the fault is measured from the point of voltage measurement.

Because the phase comparison system operates from line current alone, it is immune to out-of-step conditions. The current entering an unfaulted line section at one end is always equal to that leaving at the other, regardless of system swings. On the other hand, the distance elements used in the directional comparison schemes may operate on out-of-step conditions or system swings. This occurs whenever the impedance (the ratio of voltage to swing current) falls within the tripping range of the relay. To prevent the distance relay from operating on out-of-step conditions when the system electrical center falls within the protected line, additional relay elements are necessary and are frequently applied. Operation on swing currents or synchronizing surges from which the system can recover is usually preventable by application of the offset or phase-angle discriminating type of distance relay. In some cases, it may be desirable to separate the system at a particular line terminal during out-of-step conditions. Consequently, with phase-comparison carrier relays, an additional out-of-step tripping relay is sometimes necessary unless the back-up relays provide this operation. Other advantages of the phase-comparison system are its immunity to false operation as a result of zero-sequence induction from parallel lines, unequal closure of breaker poles, and loss of potential because of blown potential transformer fuses or other causes.

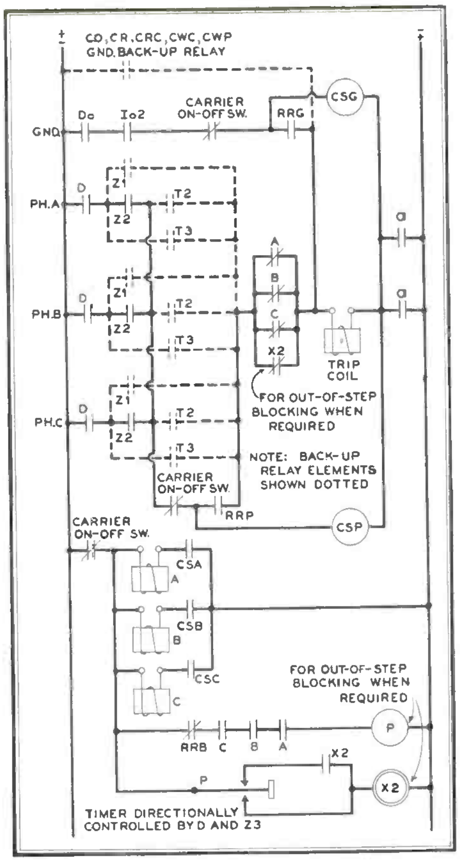


FIG. 3. DIRECTIONAL RELAYING TRIP CIRCUITS

Fields of Applications:

Normal application of the phase comparison carrier system is limited to those lines on which an adequate margin between load and fault currents exists at all times. This is because the fault detectors are current-operated devices. The fault detector settings should be high enough to permit resetting on heavy load currents after an external fault is cleared, yet low enough to trip on internal faults during minimum generation periods. On the basis of primary amperes, the same settings must be made at each end, in order to assure proper blocking on all external faults. It is often difficult to meet these requirements on lines where a small magnitude of fault current is fed through one terminal.

On a two-terminal line, the carrier-trip fault detector current setting is about 125% of the current setting for the carrier-start element. This assures positive carrier starting at both terminals on any fault-current magnitude sufficient to operate the tripping elements. Equal settings for the starting and tripping elements are not satisfactory because differences in current transformer performance, variations in relay element calibration, and other small errors might result in operation of the tripping element at one end, but not the starting element at the other end, during remote external faults. Based on a ratio of fault detector drop-out to pickup of approximately 75% to 80%, the minimum internal three-phase fault current through any terminal should be about 165% of the maximum load current. The relay filter can be set for about equal three-phase and phase-to-phase value. For ground faults, the relay can be set to 4 or 8 times the phase-to-phase fault sensitivity.

If load and fault currents on the line to be protected do not meet these requirements for the application of the phase-comparison system, several alternatives can be considered. One is connection of the sequence filter for operation on negative and zero-sequence currents only. This eliminates response to all three-phase faults, and sensitive settings can be made without regard to load for all phase-to-phase and all ground faults. Three-phase faults, which are relatively infrequent, must be cleared by the back-up relays in such applications.

Another alternative is to permit the fault detectors to close during heavy load periods. The relays then trigger back and forth, indicating a sustained external "fault" and correctly preventing tripping. This alternative requires that the carrier relay channel not be used for auxiliary functions such as voice

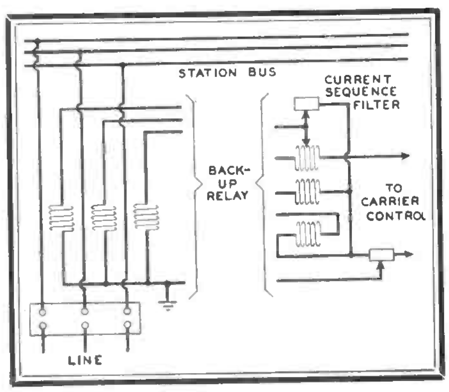


FIG. 4. AC SECTION, PHASE-COMPARISON SYSTEM

[3]For a detailed discussion of microwave relaying systems, see "Microwave Protective Relaying," Radio Communication for October and December, 1952.

communication, telemetering, supervisory control, or load control, unless it is permissible to interrupt these functions during heavy load periods. This method has been used, but continuous transmission of carrier is not generally acceptable because momentary interruption for any reason results in incorrect tripping. Another objection raised to continuous operation is the interference which may result with other carrier functions on nearby channels. However, this can be reduced or eliminated by proper trapping and selection of frequencies.

In general, however, even where the first choice is the phase-comparison system but the required margin between minimum fault and maximum load is not available, the directional-comparison scheme is usually applied rather than the alternatives outlined. The problem of discrimination between load and fault is practically eliminated in the directional-comparison system. The distance elements compare system voltage against current and operate when the ratio (impedance or reactance) is less than a definite value called the balance point. On internal faults, this ratio is less than the balance-point value, and the elements operate. In most applications, the ratios of normal voltage to load current (load impedance) are always considerably higher than the balance-point values, which means that the relays are independent of load. On long or heavily-loaded lines, of course, the impedance during maximum load may approach or even go below the impedance presented by a fault, but in these cases discrimination between the two is available on the basis of impedance angle. Load impedances have nearly unity power factor, but fault impedances are highly reactive. Therefore, distance relays with phase-angle discrimination can be applied. Both types of relays can detect fault currents of smaller magnitude than load currents and, for two-terminal lines, are practically independent of variations in fault current. Thus, the directional-comparison scheme is applicable to practically all lines, whereas in many cases the phase-comparison system cannot be used. The directional comparison system, therefore, is considerably more versatile.

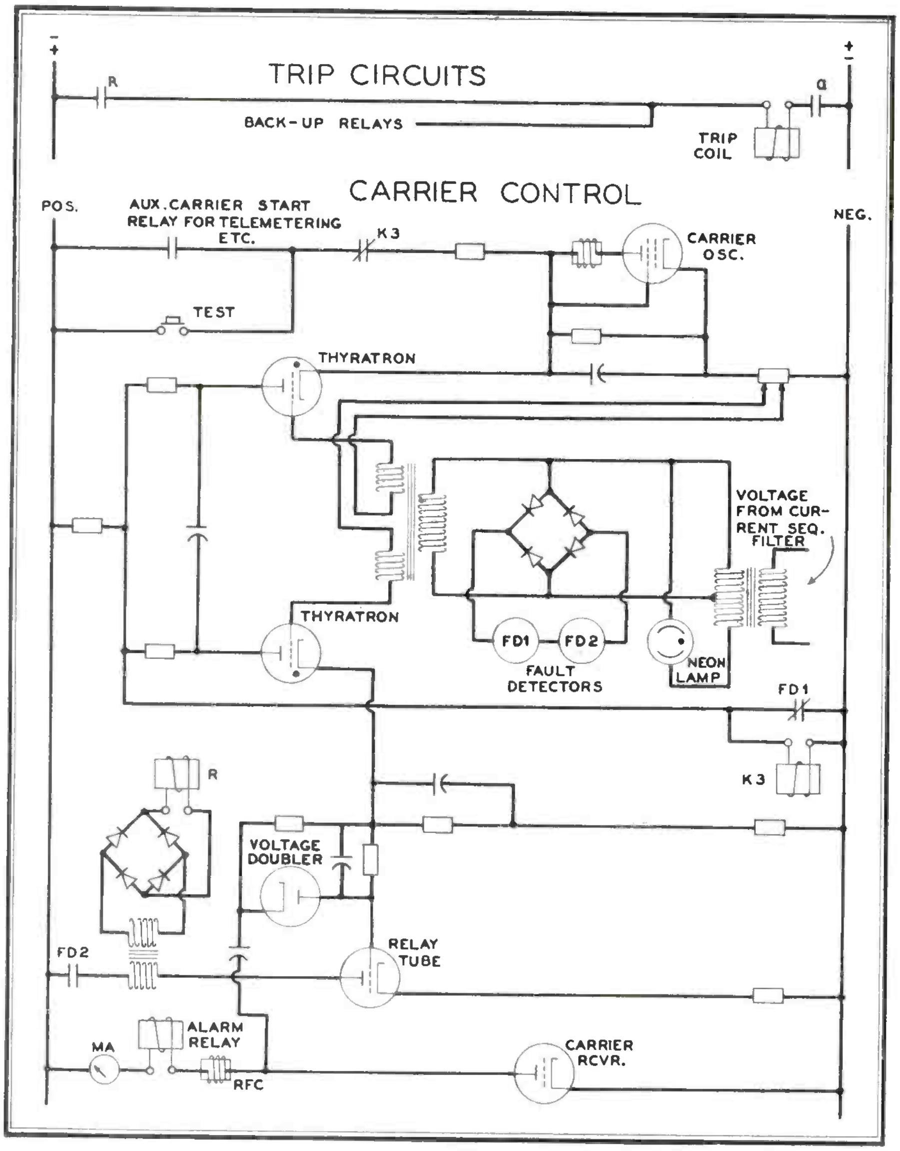


FIG. 5. CARRIER-CONTROL AND TRIP CIRCUITS FOR A BASIC PHASE-COMPARISON RELAYING SYSTEM

Multi-Terminal Line Protection:

The versatility of the directional-comparison system is demonstrated further in the protection of multi-terminal lines.[4] These can be divided according to two general types:

1) Transmission lines interconnecting more than two large stations.

2) Transmission lines tapped to supply loads.

There are many variations of each, in addition to combinations of both. Except in unusual cases, high-speed protection, if possible at all, is possible only with pilot-type relaying. The methods of protecting either type of line are similar, and because the second type usually presents the most difficult problems it will be considered in some detail.

A typical line is illustrated in Fig. 6. The transmission line connects two large sources, A and B. Each circle represents many generators, substations, loads, and interconnecting lines. A large load area at C is served by tapping the line. The transformer bank is delta or Y-ungrounded on the transmission-line side. If it were not, ground faults on the line would be supplied from this point, which would be a ground source. Although C is basically a load, there may be some local generation available, as indicated by the small circle. A great amount of rotating equipment at the tap will feed back momentarily a sizeable amount of power to faults on the transmission line. It is this limited but still not negligible back-feed through the tap that complicates tapped-line protection, as compared with protection of lines with major power sources at all terminals.

The phase comparison system can be applied generally to three-terminal lines if the margin between the trip and start fault-detector settings can be increased to about 250%. For external faults on three-terminal lines, half the fault current through the relay nearest the fault might be supplied through each of the other terminals. Therefore, the tripping element at the terminal receiving the total current must be set to more than twice the setting of carrier at all three elements at the other two terminals. This insures initiation of carrier at all three ends, as is required for proper phase comparison and blocking on the external fault. Thus, for three-terminal operation, the minimum internal three-phase fault current through

[4] "Relay Protection of Tapped Transmission Lines," by M. A. Bostwick and E. L. Harder, *AIEE Transactions*, Vol. 62, October 1943, pp. 645-50.

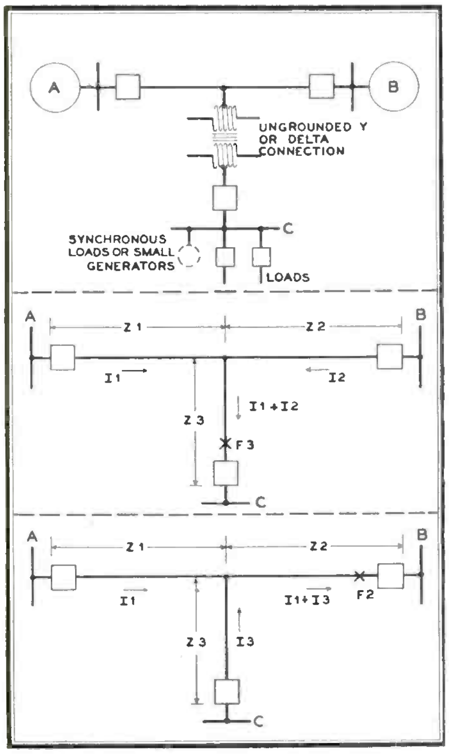


FIG. 6, TOP: LOAD-TAPPED TRANSMISSION LINE
FIG. 7, CENTER: CURRENTS FOR FAULT AT LOAD
FIG. 8, BOTTOM: CURRENT FLOW FOR FAULT AT B

any terminal should be about 333% of the maximum load current through any terminal.

The application of phase comparison carrier relays to each of the three terminals for the line, Fig. 6, is not usually satisfactory on the basis of the settings outlined, particularly with a limited source of fault power at C. When the generation or back-feed at C is negligible, then phase-comparison relays may be, under certain conditions, applied at A and B and set for two-terminal operation. These conditions are 1) that the maximum load current through relay A or B to the tap be less than 25% of the three-phase carrier-start fault-detector pickup current of the relays, and 2) that the maximum three-phase fault current contribution through either relay A or B for faults at the bus C be less than 50% of the three-phase carrier-start fault-detector pickup current.

The tap load can cause incorrect operation if it is too large. This occurs on a remote external fault when fault current is of the same order of magnitude as the load current. The worst condition occurs when fault and load current add directly, and it is on this condition that the criteria given are based. If too much load is taken by the tap, this load plus the external fault current may exceed the trip value at one end while at the other end the through fault component plus any small increment of load current flowing through the line may be less than the carrier start current. When this occurs, incorrect tripping at one end results. The relay farthest from the fault is the one that trips, regardless of the direction of load current flow. Separating the trip and start values by more than the 25% indicated above permits of a larger tapped load. Under these conditions, however, the margin between minimum internal fault and maximum load is increased. Any increment of fault current supplied by the load to the external fault flows through the relay nearest the fault. This increases the total current at this terminal and tends to prevent incorrect operation. The fact that fault and load currents seldom add at the same angle also tends to increase the safety margin.

The second requirement delineated must be met in order to prevent the relay from operating on faults on or beyond the tap bus C. These faults should be cleared by the bus differential or feeder-circuit relays, but they appear to the carrier relays at A and B as internal faults. The value of 50% is based on operating the phase-comparison relay sequence filter with increased sensitivity to negative-sequence currents, and assuming phase-to-phase fault currents are approximately 86% of the current for three-phase faults at the same location. This condition occurs when system $Z1=Z2$. If the filter combination with less sensitivity to negative-sequence current is used, the value is 73% rather than 50%.

If the transformer bank is large (low impedance) compared to the total line impedance, it will not be possible to avoid operation for bus faults at C and still obtain operation for faults on the line itself between A and B. Under these conditions, a carrier blocking terminal is required at the tap. If the back-feed through the tap is small, this can consist of a carrier transmitter controlled by overcurrent fault detectors which operate for faults on bus C or beyond but do not operate for any faults on the line AB. These relays operate on tap faults to start transmission of a continuous carrier, which blocks the carrier relays at A and B. A ground blocking relay is required if the line side of the transformer is grounded, or if zero-sequence current can flow through the transformer bank.

With directional comparison carrier relays, the magnitude of tap load is not so critical. The impedance-type fault detectors must be set above maximum load, as previously outlined, whether the load is to the tap or beyond the line section. For proper carrier blocking on any line, the carrier-start fault-detector at each terminal must reach farther behind the protected zone than any carrier trip (stop) element at the other terminal or terminals. In other words, the distance-type carrier-start element at B on line AB, Fig. 6, must reach farther into the system to the right of bus B than the distance-type carrier trip element at A or at C. Similar conditions apply to A and to C if carrier relays are used at those points. The elements must be set so that any load current at A or B to C, when combined with the fault current resulting from a remote external fault beyond A or B, cannot operate the trip element at the terminal remote from the fault without operating the start element at the near terminal.

The distance elements for a tapped line, such as in Fig. 6, must also be set so as to operate for all internal line faults, and *not* to operate for faults on the bus at C. If this is impossible, a carrier blocking terminal must be established at the tap. Again, this is dependent on the location of the tap, and the size of the transformer bank in relation to the line and interconnected system. With a breaker on the line side of the transformer bank, such blocking is always needed to prevent tripping of the remote breakers on faults that can be cleared by the transformer breakers and relays.

Unfortunately, the impedance seen by the relays on a tapped or multi-terminal line is not always the actual line impedance from the relay to the fault. Instead, an apparent impedance is seen which is usually larger than the actual impedance. This effect, and the resulting requirements for relay settings, can be outlined by a discussion of Figs. 7 and 8. These show the same system with faults at different locations. The fault is at the tap in Fig. 7, while in Fig. 8 it is at station B. The settings at station A for the three-zone type distance relay used in the directional comparison carrier system can be determined as follows:

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TABLE 1 — ADVANTAGES AND DISADVANTAGES OF EACH SYSTEM

POWER DIRECTIONAL COMPARISON	CURRENT PHASE COMPARISON
Contains more mechanical elements.	Contains more electrical elements.
Potential source required.	No potential source required.
Contains phase back-up elements.	Back-up protection entirely separate, hence can be used with existing relays as back-up.
May trip on swings or out-of-step unless special elements are added.	Will not trip on swings or out-of-step conditions.
More applicable to multi-terminal and tapped lines.	Restricted application to multi-terminal or tapped lines.
Can operate on fault currents less than load currents.	Margin between maximum load current and minimum fault current recommended.
Generally more flexible to system changes and addition of tapped loads.	

PERFORMANCE TESTS

(Continued from page 18)

The locations tested were as follows:

A: On the Long Lines building, a 27-story building in downtown Manhattan.

B: On the Graybar-Varick building, a 16-story building in downtown Manhattan.

C: On the telephone building which houses the Melrose exchange, a 7-story building in the center of the Bronx.

D: On the 3-story telephone exchange building in Lynbrook, Long Island.

Table 1 describes the generally prevailing noise situation at these locations. Higher noise was encountered occasionally at some of the sites, due in at least one case to operation of elevators in the building. However, these occasions were so brief and infrequent that the general background of noise is considered to be a better value to use in estimating systems performance.

The trend toward lower site noise at higher frequencies, already noted for mobile installations, is seen to apply to land receivers as well.

These data bring out another interesting and significant fact. Where noise collected by a dipole antenna is discernible over set noise, the noise collected by the 7-db gain antenna at the same site is, surprisingly, less. This means that the gain antenna picks up *less* noise power than a dipole. Since it picks up 7 db more signal from a distant car, a gain antenna thus provides a double improvement in transmission at those sites for which ambient noise is the controlling factor.

TABLE 1: RF SIGNAL INPUT TO RECEIVER FOR 12-DB SPEECH-TO-NOISE RATIO (GIVEN IN DB ABOVE THAT NEEDED TO OVERRIDE SET NOISE*)

Station	Frequency	Antenna	
		Dipole	7-db Gain
A	150 mc.	10	—
	450	1	0.5
	900	—	1.5
B	150	12	—
	450	4	—
	900	0	—
C	150	11	2.5
	450	1	1
	900	1	—
D	150	5	4
	450	0	0
	900	0	—

*Noise figures in the test receivers were 9, 12, and 12 db for 150, 450, and 900 mc., respectively.

An explanation of this behavior may be surmised if it is assumed that the sources of noise are numerous and are scattered around at street level (motor vehicles, mostly). The overall noise received is a sum of contributions from all sources, weighted for distance and the receiving antenna pattern. A gain antenna of the type considered here tends to ignore the strong nearby noise sources because they are below the antenna beam. The sources which are nearly enough in the beam to count are also farther away, and are attenuated by distance.

The amount of data given in Table 1 does not seem sufficient to warrant stating a firm figure as to the amount of improvement obtainable from a gain antenna. However, substantial improvement at 150 mc. is indicated, and this might have the effect of bringing the value of mobile transmitter power required at 150 mc. down to the value required at 450 mc., assuming gain antennas in both cases.

Acknowledgments:

A number of people participated at one time or another in setting up and carrying through these tests. It is not possible to name them all, but the principal participants were R. L. Robbins, R. C. Shaw, W. Strack, D. K. White, and F. J. Henneberg. The program was supervised by D. Mitchell. The special radio equipment required was designed and furnished by W. E. Reichle and his group.

HANDIE-MICRO-TALKIE

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the chassis to avoid crossovers. Second, because the solder flows by capillary action up the lead and plated hole wall to grasp on both sides of the plate, the mechanical strength of the connection is increased, as shown in Fig. 9. Some holes in the Bakelite are square rather than round, thus preventing any circular rotation within the holes if leads are dressed after soldering or if any strain is put on them. The third advantage is that, where it is necessary to have very high bonding strength, all that need be done is to add a hole every so often along the path of the conductor. Because of the eyelet action, this anchors the plated conductor to the Bakelite base.

The materials cost of a Bakelite PLAcir chassis, with plating on both sides, is nominal. Also, there is an inherent reduction in wiring errors. It is

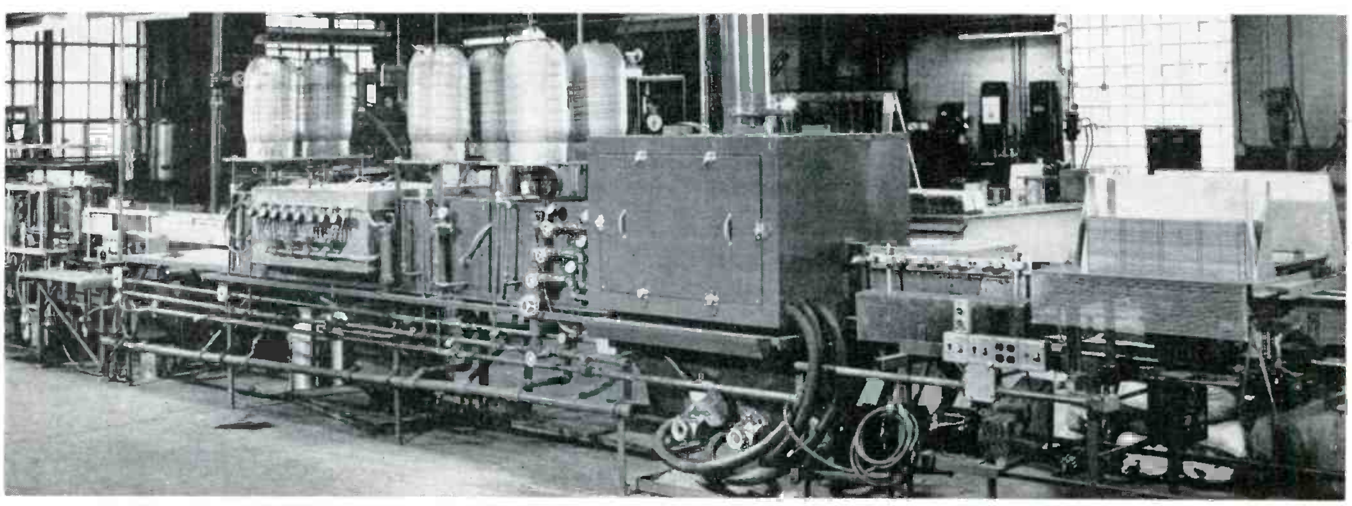

FIG. 10. A VIEW OF AN AUTOMATIC PROCESSING UNIT FOR PREPARING, SCREENING, AND PLATING THE PLACIR PRINTED-CIRCUIT BAKELITE CHASSIS

almost impossible to place components in the wrong holes. Once a unit is soldered, there is no cause for worry about wire-breakage or of shunt capacities changing.

Inspecting, testing, and labor costs are reduced because of the automatic soldering. It is possible also to eliminate many terminal boards. Since the chassis is non-metallic, all that is necessary to isolate a plated hole is to leave a perimeter of unplated Bakelite around it.

The automatic dip-soldering process can be used, if desired, wherein all component leads are placed through their respective holes in the piece and the entire under side of the piece is dipped into a hot solder pot, thus soldering all connections at once. However, an automatic touch method of soldering has been developed for use in conjunction with the PLAcir process. With this method, it is possible to mount components on both sides of the plate, which cannot be done when using the dip-solder technique. As the Bakelite chassis, with all components in place, moves down the production line, it stops over a solder pot. A series of small arms rise up through the solder pot. Each arm has a small cup on top which is, in effect, a subminiature solder pot. The arms reach up to the under side of the chassis, and one touches each place where a soldered connection is to be made. All connections are soldered individually and at once. The chassis then moves farther down the line where it is turned over, parts are mounted on the other side, and the entire process is repeated.

In production, a large screen can be made which is capable of screening 10 to 20 pieces at one time, or even more. Accordingly, the Bakelite chassis are made, drilled, and punched with many chassis on one large sheet. After all screening is done, this large sheet is sheared into the small individual chassis. The actual preparation, screening, and plating of the Bakelite chassis is fully automatic. Fig. 10 is a view of one of the automatic PLAcir process units.

All edges and walls of holes are plated in this process because no resist ink is applied there. However, if it is desired not to plate these points, a process of reinsertion has been developed. These particular holes are punched out, and the material which made up the holes are reinserted in their proper locations in the same operation. Such holes aren't plated; the waste material is knocked out at some time after plating. Thus, a component part can be recessed into the bakelite or, if the plated chassis is an irregularly shaped piece, the waste material it was punched from can be used as the carrier of this piece through

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HANDIE-MICRO-TALKIE

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the entire process. Because it is relatively easier to handle uniform rectangular pieces than odd-shaped ones, handling costs are reduced.

Conclusion:

Through the application of new techniques for plated circuitry, and the incorporation of three-dimensional design, it has been possible to reduce the size of this transmitter 30% below any other comparable unit. The weight reduction over conventional methods is on the order of 40%. While techniques of this type lend themselves perfectly to the production of small units, they do not seem applicable, at the present time, to standard mobile equipments.

RELAYING SYSTEMS

(Continued from page 33)

The first-zone elements, which must not reach outside the protected line, must be set at 80% to 90% of the ohmic distance to the nearest remote bus. For relay A, this 80 to 90% of Z1+Z2 or Z1+Z3, whichever is least. These are *actual* ohms. Suppose Z1+Z3 is the smaller value. Under fault conditions, with all breakers closed, relay A sees an apparent impedance which is (Fig. 7)

$$Z = \frac{V}{I} = \frac{I1Z1 + (I1+Z2)\,Z3}{I1}$$

$$= Z1 + Z3 + \frac{I2Z3}{I1}$$

Thus, the apparent impedance is larger than the actual impedance by the ratio of the fault current from B to that from A, times the impedance from the tap point to the station C. To the first-zone element of the distance relay at A, fault F3 appears farther away or, in other words, the reach of the first-zone element shrinks as I2 becomes larger in proportion to I1. The limits are,

First-zone element covers full distance as set (90% of Z1+Z3) only when breaker at B is open, or I2=0.

First-zone coverage will shrink toward but never reach the tap point as I2 increases.

The second zone of the distance relay must extend beyond both remote buses under all conditions, in order to provide carrier protection for the entire line. Therefore, it must be set for the maximum apparent ohms under all fault conditions. For the relay at A and the fault at C. Fig. 7.

$$\text{Apparent ohms} = Z1 + Z3 + \frac{I2}{I1} Z3$$

For a fault at B, Fig. 8,

$$\text{Apparent ohms} = Z1 + Z2 + \frac{I3}{I1} Z2$$

The maximum apparent impedance may occur either during maximum or minimum generating conditions, or during operation conditions under which various lines are out of service. In some cases, the apparent impedance will be very large; such a condition often requires the application of the long-line or offset-type distance relay. This is true for a station with a small source of power, such as C, compared to the large sources at A and B. Thus, a long reach is necessary at C for operation on faults near or at stations A and B. However, when breakers at A and B are open or out of service, the reach of the second zone extends considerably beyond the remote buses, depending on the ratio of the apparent to the actual impedance. The second-zone element, therefore, operates for quite remote external faults under these conditions, and difficulty is often experienced in coordinating the time setting of the second-zone back-up timer with other protective relays that are overreached by the element with the third-terminal breaker open.

The requirements for setting the third-zone element for carrier starting or blocking have been outlined. In many cases, a long setting is required in order for the third-zone element, looking behind the line section, to reach beyond the second-zone elements at the other terminals under all conditions.

It is for these reasons that offset-type distance relays are commonly applied to multi-terminal lines, with the third-zone element offset in the backward-direction. Because of variations in the operating zones of these relays, back-up protection may be slow and unsatisfactory or, perhaps, may have to be eliminated entirely. However, the directional carrier is more flexible than the phase comparison type, and can usually be applied to provide high-speed protection for the multi-terminal line, even though compromises are sometimes necessary.

The problems of applying distance-type relays on tapped or multi-terminal lines have been discussed on the basis of relaying phase faults. The same considerations apply to distance-type ground relays, except that load current does not flow in the operating element and does not affect settings or operation. With carrier, the less-complex directional-overcurrent ground relays are used rather than distance-type ground relays, except in rare cases, because they are not affected directly by load currents. They can be set to operate sensitively on all internal faults for nearly all variations

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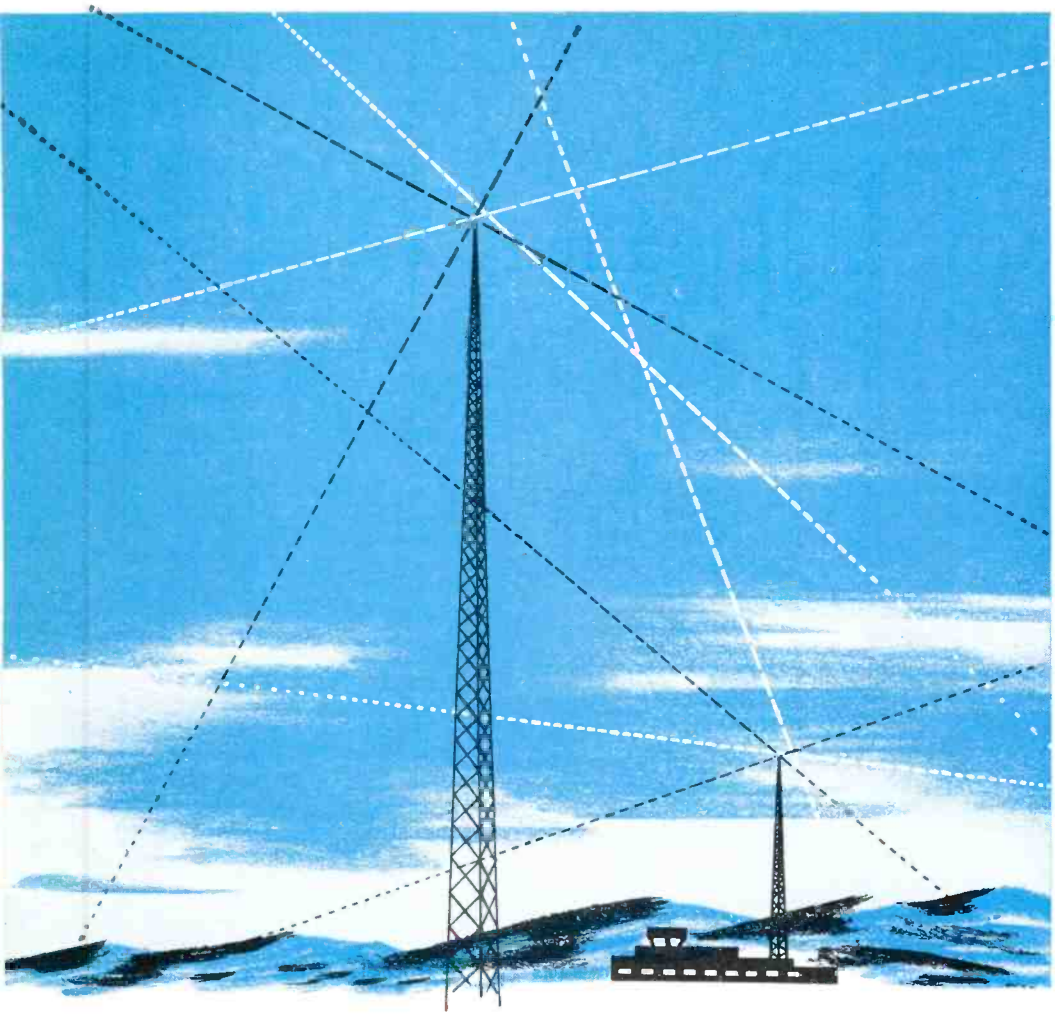

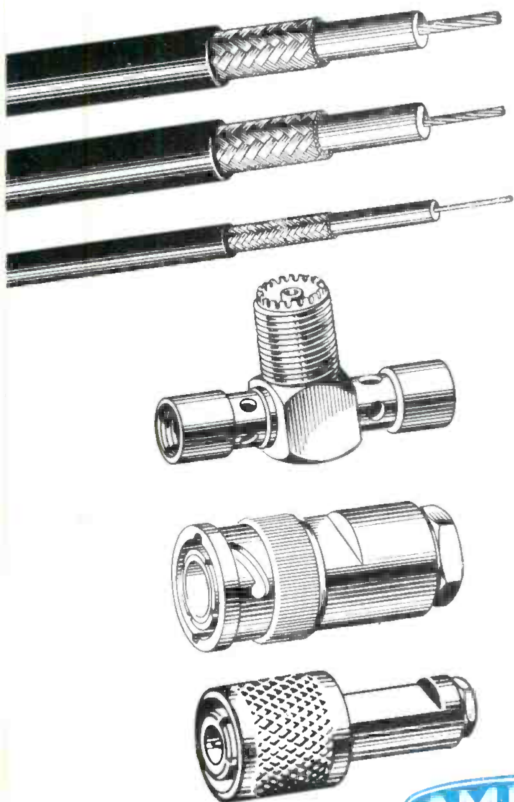

RELAYING SYSTEMS

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in distribution. The carrier-start element is set to operate at a low current level such that it always operates on any external fault behind it, which operates the tripping and directional elements at the remote terminals.

The most difficult relaying problems are usually encountered when the tap generation of fault power back-feed is light, and high-speed or immediate reclosing is required. If the generation is small at C, Fig. 8, and it is necessary to open C simultaneously with A and B, the problem is to relay C even though the fault power fed through C is insufficient to operate conventional protective relays, but is enough to maintain the fault arc and prevent reclosure. Without reclosing, sequential or time-delay tripping of C would be satisfactory. Transferred tripping offers a good solution, provided it can be obtained instantaneously. In this scheme, the operation of relays A and B initiates tripping of the breaker at C.

In the application of carrier relays, it is assumed that current flows into the line at all terminals for internal faults. If current flows out, as can happen on some multi-terminal lines, then the carrier relays are blocked until the breaker nearest the fault is tripped. A line of this type is best protected by directional comparison carrier relays by which the first-zone element, which is independent of carrier, trips the breaker near the fault. After this breaker opens, the redistribution of fault current causes current to flow toward the fault at the other two terminals, and the carrier relays trip. This is high-speed sequential tripping. Such operation may be necessary also on lines where the apparent impedance to one or more terminals is too high for any satisfactory relay setting. Clearing of the fault by the first-zone elements of the relays nearest the fault causes the relay which previously worked into a high apparent impedance to reach out and trip sequentially.

Protection of Short Lines:

A pilot-wire relaying system is ordinarily first choice in the protection of very short transmission lines. The basic factor influencing this choice is usually economy. Occasionally, however, pilot wires are for some reason impractical, and consideration must be given to carrier or microwave radio for the relaying channel. If the line consists wholly or in part of underground cable, the use of microwave radio should be considered.

On short two-terminal lines, the phase comparison system can be used. On three-terminal lines, however, the application of phase comparison must be considered carefully in line with the previous discussions. The directional comparison system with distance relays cannot be applied in every case to extremely short lines, because the fault voltages and line impedances may be too low for proper settings of the relays or for positive relay action.

Conclusions:

The two basic carrier relaying types are the phase comparison and the directional comparison systems. The advantages and limitations of each, as outlined in this paper, are summarized in Table I. In general, the directional comparison system is more versatile, particularly for the protection of multi-terminal lines, but the phase comparison system has some distinct advantages when it can be applied. The overall complexity is about equal when back-up relaying is included in the comparison.

From the two basic types, the relay protection engineer must select the system best suited to his particular application, taking into account such factors as economics, system operating requirements, previous experience, and the available facilities for indications of faults and troubles. It is these factors that make each relaying problem distinctively individual, and which make protective relaying as much an art as it is a science.

REVIEW

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munication common carriers. This situation in which the Commission did assume jurisdiction, is distinguishable from the situation under consideration, since the Commission had before it in that case the question of the lawfulness of a tariff provision applicable to the furnishings of interstate common carrier service and facilities for video program transmission over which the Commission has full jurisdiction. In the case of privately-owned microwave system, however, the common carrier facility involved, *i.e.*, the PBX board on the microwave operator's premises, is essentially a local facility not subject to the jurisdiction of the Commission, except to the possible limited extent of its use to originate or terminate long distance calls over telephone company long distance facilities. Thus, Section 201 (b) of the Communications Act is probably not applicable, since the common carrier facility is, for the purposes of interconnection with private microwave facilities, essentially a local facility not subject to the Commission's jurisdiction.

That does not mean however, that the

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FCC would not be interested in reports on all developments, and in conferring on such matters with the representatives of the affected users of radio and those of the telephone company, regardless of the jurisdictional position taken. The continuing interest of the FCC in this subject can be explained on a number of grounds but it is perhaps enough to state that the Commission is under statutory obligation to recommend annually new legislation to the Congress [Communications Act, Section 4 (k)] and that the telephone company's refusal of interconnection may be tantamount to a negation of the public interest determination reached by the Commision in authorizing the radio circuits involved. Even though the Commission may decline jurisdiction to order the establishment of the desired interconnection, it should not decline to consider very seriously the position of any aggrieved microwave user.

Position of State Commissions: What will be the position of the state regulatory commissions to whom these matters may be referred? Here we have one very definite guide in what is believed to be the only reported case on the precise subject,[2] in which the Department of Public Service of the City of Houston concluded that it had jurisdiction of the complaints of Transcontinental Gas Pipe Line Corporation and Humble Oil and Refining Company and Humble Pipe Line Company against the Southwestern Bell Telephone Company for failure to provide termination service for their microwave systems.[3]

T. G. P. L. and Humble Cases: In these cases, considered simultaneously, the Transcontinental and Humble microwave installations were the usual company communication systems. The Transcontinental system extended from Falfurrias, Texas to Newark, New Jersey with 58 points at which calls could be originated or received. The Humble system connected the company's Kemper Station near Big Lake in Reagan County, Texas, with Houston, Texas. Both Transcontinental and Humble had telephone company PBX boards at their Houston office buildings connected with all the office telephone instruments and

[2] L. D. 13,084—In the Matter of the Complaint of Transcontinental Gas Pipe Line Corporation against Southwestern Bell Telephone Company for Failure to Provide Termination Service for Microwave System; L. D. 13,084—In the Matter of the Complaint of Humble Oil and Refining Company and Humble Pipe Line Company against Southwestern Bell Telephone Company for Failure to Provide Termination Service For Microwave System, decided November 6, 1951.

[3] The States of Texas and Iowa do not have regulatory Commissions.

the telephone company's central exchange. The service desired by each of the oil companies was the termination of the microwave circuit on their Houston PBX board so that the telephones in the building might be connected with the microwave system. Neither of the companies desired the connection so that a person at one of the microwave stations outside the City might call through the Bell Telephone Company's PBX board, then through the company's central telephone exchange, to another telephone somewhere outside the Humble Building, or the Transcontinental Building, as the case might be.

Decision at Houston: Holding that the termination service was a form of local-exchange service over which the City had unquestioned power of regulation, the Department of Public Service concluded that the City had jurisdiction over the complaint of the oil companies. In reaching its conclusion to assume jurisdiction of the complaint, the City noted that the Southwestern Bell Telephone Company had been furnishing privately-owned wire line termination service to oil and gas companies in Houston for a period of at least 25 years and that it did not appear from either record that the Bell Telephone Company was "concerned in the slightest as to the interstate, intrastate, or local character of the messages being carried by the private line in furnishing the termination facilities" at a monthly flat rate.

Having in the wire-line field said by their tariffs and numerous agreements that these oil companies and others similarly situated could build their own telephone lines and demand physical interconnection, the general common law rule that telephone companies are under no duty to make a physical connection with the facilities of private users was held inapplicable to the same situation in the radio field. As the Department observed: "Having made this general offering [of PBX termination service in the wire line field] to the public, it cannot now invoke this rule of law [in the radio field]."

Although the Houston decision was expressly made on jurisdictional grounds and not on the merits, there were clear implications in the decision that the interconnection would be ordered, as perhaps best evidenced by the fact that the City's conclusion of jurisdiction was followed by the telephone company's voluntary provision of the service as requested.

A Sound Precedent: While it is to be doubted that the type of PBX service in question is properly classifiable as "telephone exchange service," the City's decision was at pains to point out else-

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where that the termination service in question was "only a local service on a local switchboard." This would appear to be unquestionably the case and, as a form of local telephone service, this PBX termination service would appear properly subject to the jurisdiction of the state or municipal regulatory agency.[4] When it is considered also that the microwave system is limited to intra-company communications, and that the identical arrangements in the wire line field have not resulted in unsatisfactory public telephone service, the jurisdictional decision of the City of Houston would appear to rest on unassailable substantive grounds.

It is therefore concluded that the precedent will be followed in other jurisdictions where the problem may arise, and that the telephone companies will ultimately revise their tariffs to permit such PBX termination service for private microwave circuits. This conclusion is fortified by the knowledge that through the years the provisions of telephone tariffs have proved extraordinarily responsive to the financial facts of life; and it is understood that in some cases the telephone company denial of the connection sought has resulted in the removal of certain telephone facilities, principally telephone instruments, formerly leased from the telephone company but found capable of elimination after the installation of the intra-company radio circuit and associated private facilities.

Need for National Policy: If the results suggested above do not come to pass, however, the subject appears to be of sufficient importance to warrant the FCC or any aggrieved class of users in bringing the subject to the attention of Congress for suitable amendment of the Communications Act so as to give the Federal Communications Commission power to require such connections, after public hearing, in the same way that the FCC is now empowered to require inter-connection of facilities between common carriers.

The facts and large considerations applicable to a solution of this problem are quite simple. The use of privately-owned microwave systems is capable of enormous expansion as a tool of industry, and these installations have already proved to be so valuable that their development and growth must not be retarded.

[4]It is interesting to note, however, that the Southwestern Bell Telephone Company questioned the City of Houston's jurisdiction because of the claimed jurisdiction of the FCC over the service in question. This position of superseding FCC jurisdiction, while of doubtful legal validity, is perhaps the best practical answer to the situation.

VEHICULAR MEETING

(Continued from page 14)

tests made by RCA which compared the performance of 30 and 20-kc. channel systems in the 160-mc. band with standard 60-kc. channel systems. On the basis of a given set of system parameters, it was concluded that performance is continuously degraded by decreasing channel spacing, considering impulse noise, system stability, adjacent-channel interference, and intermodulation.

The paper by Neal H. Shepard, describing the tests made for the JTAC subcommittee at Syracuse, created particular interest because he used a tape recorder to reproduce the reception obtained under various conditions during the tests. He also ran these tapes during the panel discussion which took place the following afternoon. The Syracuse tests were made under identical conditions on equipment of 5 manufacturers, and representatives of 8 companies were present. Exhaustive field trials were made to determine:

1) What channel spacing would give the best quality of service?

2) What change in service would occur to 60-kc. systems during the transition period?

3) What interference would 60-kc. systems produce in narrow-band systems?

No conclusions were stated, since it is the task of the JTAC subcommittee to evaluate the results.

Daniel E. Noble of Motorola gave the concluding paper of the afternoon, on "Commercial Experience With 160-Mc. 20-Kc. Equipment". This was a description of an MCC system set up in Phoenix, Arizona, in order to gain actual operating experience on a split-channel 160-mc. system. His conclusion was that no special operational or maintenance difficulties were introduced by the use of this equipment.

Third Session: The morning session of the second day was opened with a paper by Rea Young, Jr., of Bell Laboratories, entitled "Comparison of Mobile Radio Transmission at 150, 450, 900, and 3,700 Mc." This paper appears in its entirety in this issue of COMMUNICATION ENGINEERING beginning on page 15. A significant conclusion drawn by Mr. Young is that least power is required for a given communication range in the vicinity of 500 mc.

Milton Dishal of Federal Telecommunication Laboratories then gave an illuminating talk on the factors affecting filter design, comparing LC, mechanical, and crystal filters. Conclusion was that the 3 are equivalent in efficiency, since the same number of filter sections is re-

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WEEKLY REPORTS

of FCC Applications Filed for New

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Since January 1, the Reports of New FCC Applications for communication systems have been available in the form of Weekly Reports, sent by first class mail or by air mail. This service has been set up because, since COMMUNICATION ENGINEERING is now a bimonthly, too much space would be required to publish the list of applications filed during two months, and there would be too great a delay in making the information available.

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This Controlled Reluctance Microphone Cartridge is an ideal service replacement for the Model 520SL Dispatcher and for use in special hidden microphone applications. Practically unaffected by heat and humidity.

Model R5 "Controlled Reluctance" Microphone Cartridge

This dispatching unit handles the most severe field requirements of paging and dispatching systems. Supplied with 2-conductor shielded cable, and wired to operate both microphone and relay circuits. Features "Grip-to-Talk, Slide-to-Lock" long-life switch.

Model 520SL "Dispatcher" Complete Dispatching Unit

Designed for use with small portable and mobile transmitters. Only 2" in diameter and 1½" thick. Has 3-conductor coiled cord, metal-spring strain relief, and Push-to-Talk switch. Has same operating characteristics as "100 Series" Carbon Microphones.

Model 115 Carbon "Pack" Microphone

A Controlled Reluctance Microphone and desk stand assembly—ideal for mobile and fixed-station use in all types of communications work. Has a built-in switch for controlling both the microphone circuit and an external relay or control circuit.

Model 510MD "Controlled Reluctance" Microphone Assembly

SHURE BROTHERS, INC.

Manufacturers of Microphones and Acoustic Devices

225 W. Huron St. • Chicago 10, Ill.
Cable Address: SHUREMICRO

VEHICULAR MEETING

Continued from page 44

quired, but that considerations of use and manufacture determine the best type for any given purpose.

Following this, a paper by L. J. Labrie of Bell Laboratories was given, describing new design and manufacturing techniques for high-frequency crystals which result in marked spurious-response suppression. This makes for greater utility in the design of selective IF filters for communication applications, where crystal filters have an advantage in that higher IF frequencies can be employed

Concluding Session: Leading off in the fourth and final technical session, E. N. Singer of the FCC gave a talk on "FCC Rules and Their Enforcement in the Vehicular Services."

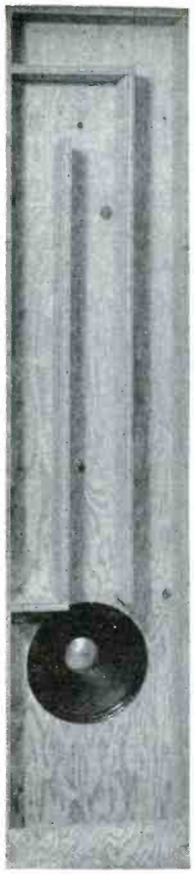
This was followed by a panel discussion on "Increased Utilization of the Mobile Bands." About a dozen well-known engineers were asked questions from the floor on any of the papers given at the meeting or on any subject pertaining to vehicular communication.

The concluding event was a banquet at which the Washington Section of IRE joined the members of the Vehicular Radio Group. Dr. Lloyd V. Berkner, president of Associated Universities, Inc. was toastmaster, and Haraden Pratt, Telecommunications Advisor to the President, was the speaker of the evening.

Demonstrations by equipment manufacturers were given the following day. RCA showed 450-mc. equipment, Motorola demonstrated the operation of its 450-mc. installation for the Washington AAA, and General Electric had a setup for showing the relative performance of wide-band and narrow-band equipments under conditions of strong signals, marginal signals, and noise interference.

INDEX OF ADVERTISERS

FOR YOUR CONVENIENCE, TELEPHONE NUMBER OF EACH COMPANY IS SHOWN HERE



FAS Air-Coupler for Bass Reinforcement

Good News . . . The Dual Air-Coupler for bass reinforcement is in stock, ready for delivery. This is the improved model described in **Radio Communication last October**, and in the Winter Edition of **High Fidelity**.

As more and more of the most critical audio experts install Air-Couplers in extended-range systems, reports of remarkable performance continue to pour in. One of the most enthusiastic owners is Paul deMars, former chief engineer of the Yankee Network, and a pioneer in high-quality reproduction. He said: "I have never heard such magnificent tone from records and live-talent FM as I am getting from my Air-Coupler in combination with a dual speaker for intermediate and treble frequencies."

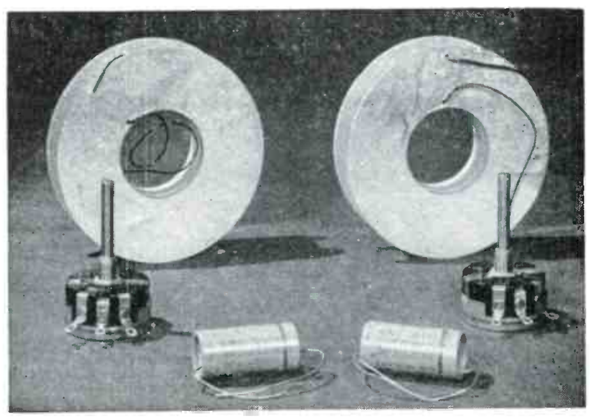
For your convenience . . . the Air-Coupler is available in both knock-down form, so that you can assemble it with a screwdriver, or completely assembled, ready to mount the speaker. Made entirely of first-quality ¾-in. plywood, with each piece cut to precision fit.

DUAL AIR-COUPLER, COMPLETELY ASSEMBLED ... **now only 47.50**
The Air-Coupler is supplied completely assembled and finished in a truly professional manner, with front panel in place, ready for the speaker. Illustration shows assembled Air-Coupler, before front panel is mounted. Opening is cut for any 12-in. speaker, the recommended size.

DUAL AIR-COUPLER, IN KNOCK-DOWN FORM ... **now only $34.50**

MISCELLANY: we carry in stock . . . **Altec 600-B** 12-in. speaker for the Air-Coupler, $46.50; **Peerless S-230Q** output transformer, $26.00; **Peerless R-560A** power transformer, $16.00; **Peerless C-455A** power choke, $10.00; **English KT-66** output tube, $4.95; **Racon CHU2** tweeter, $23.10.

Crossover Networks for Any System of Two or More Loudspeakers



By a judicious selection of associated components, the three coil sizes on which G.A. has standardized enable our customers to secure low-cost crossover networks which will operate at 14 different crossover frequencies! For the experimenter, that means a wide range of choice without having to break the bank to buy dozens of coils. For the man who wants to install his system once and for all, it means money saved, because G.A. saves money by making only three coil sizes (10.2, 5.1, and 1.6 Mh) — and it passes on those savings direct to its customers.

If you want to use three speakers with crossover points at 350 and 1,100 cycles, for example, just order two of the networks listed above (for an 8-ohm system, with rapid crossover attenuation, it would be No. 6 and No. 8).

As most everyone has found out by now, G.A. is headquarters for crossover networks. As far as we know, we're the only organization stocking networks **specifically designed** for use with Air-Couplers.

If you are in doubt about the selection of a network for your particular speakers, send 10c for the G.A. Network Data Sheet, from which you can determine your requirements exactly.

RAPID ATTENUATION NETWORKS

12 db droop per octave. These networks use two inductance coils.

Impedance of low frequency speaker	Crossover Frequency	Order by Number	Price 2 Coils Only	Price Complete*
16 ohms	2,200	No. 1	$7.00	$11.50
	1,100	2	7.00	12.00
	700	3	12.00	16.00
	350	4	12.00	17.50
	175	5	20.00	24.00
8 ohms	1,100	6	7.00	12.00
	550	7	7.00	13.00
	350	8	12.00	17.50
	175	9	20.00	24.00
	85	10	20.00	26.50
4 ohms	550	11	7.00	13.00
	275	12	7.00	15.00
	175	13	12.00	19.00
	85	14	20.00	26.50

* Complete networks include necessary capacitors and level controls. Be sure to indicate whether you want just the coils or the complete network.

Air-Couplers are shipped via Railway Express, FOB South Egremont, Mass.
Other items shipped FOB unless 75c is included to cover parcel post and insurance charges.

General Apparatus Co.

South Egremont, Massachusetts

NEW BOOKS

Radio License Examinations, third edition (revised), by Charles E. Drew. John Wiley & Sons, 464 pages, $5.75. CE Book Dept. No. 103.

The main difference between this and the third edition is the addition of material on elements 7 and 8 of FCC license examinations, covering technical, regulatory, and operational practices of aeronautical communication and navigation, and marine radar. Further material has been added also, relevant to restricted and third-class radiotelephone and radiotelegraph permits, as well as some minor revisions in material for second and first-class licenses. The unusually broad and accurate information contained in this question-and-answer text, as well as the very complete appendix, make it a valuable book to anyone studying for an FCC license examination.

Harmonics, Sidebands, and Transients in Communication Engineering, by C. Louis Cuccia. McGraw-Hill. 465 pages, $9.00. CE Book Dept. No. 104.

In line with the admirable trend shown in recent years toward the integration of pure mathematical treatises with their practical applications, the author of this book has attempted to convey the mathematics of harmonic and transient analysis while, at the same time, treating the field of communication engineering in its own right. He has been reasonably successful in doing so, but his field is so broad that it is impossible to cover all aspects thoroughly. For instance, only 30 pages can be devoted to linear-network analysis; only 33 to amplifier distortion and harmonics. An excellent book for gaining a broad general knowledge of the subject, such as is desirable for a college student, but not adequate for those specializing in one of the many applications covered.

Filter Design Data for Communication Engineers, by John H. Mole. John Wiley & Sons. 252 pages, $7.50. CE Book Dept. No. 105.

Here is a book which should prove invaluable to the design engineer working on specialized filters of all kinds. The author concentrates on the Zobel methods of synthesis for low and high-pass filters, symmetrical and dissymetrical band-pass and band-stop filters, impedance transformation, junction losses and effective loss calculation, and terminal section design. Tchebycheff theory and behavior are covered quite well with sections on stop-band attenuation, pass-band loss, the effects of dissipation, and tolerances on element values. Especially valuable is the collection of charts, tables, and formulas.