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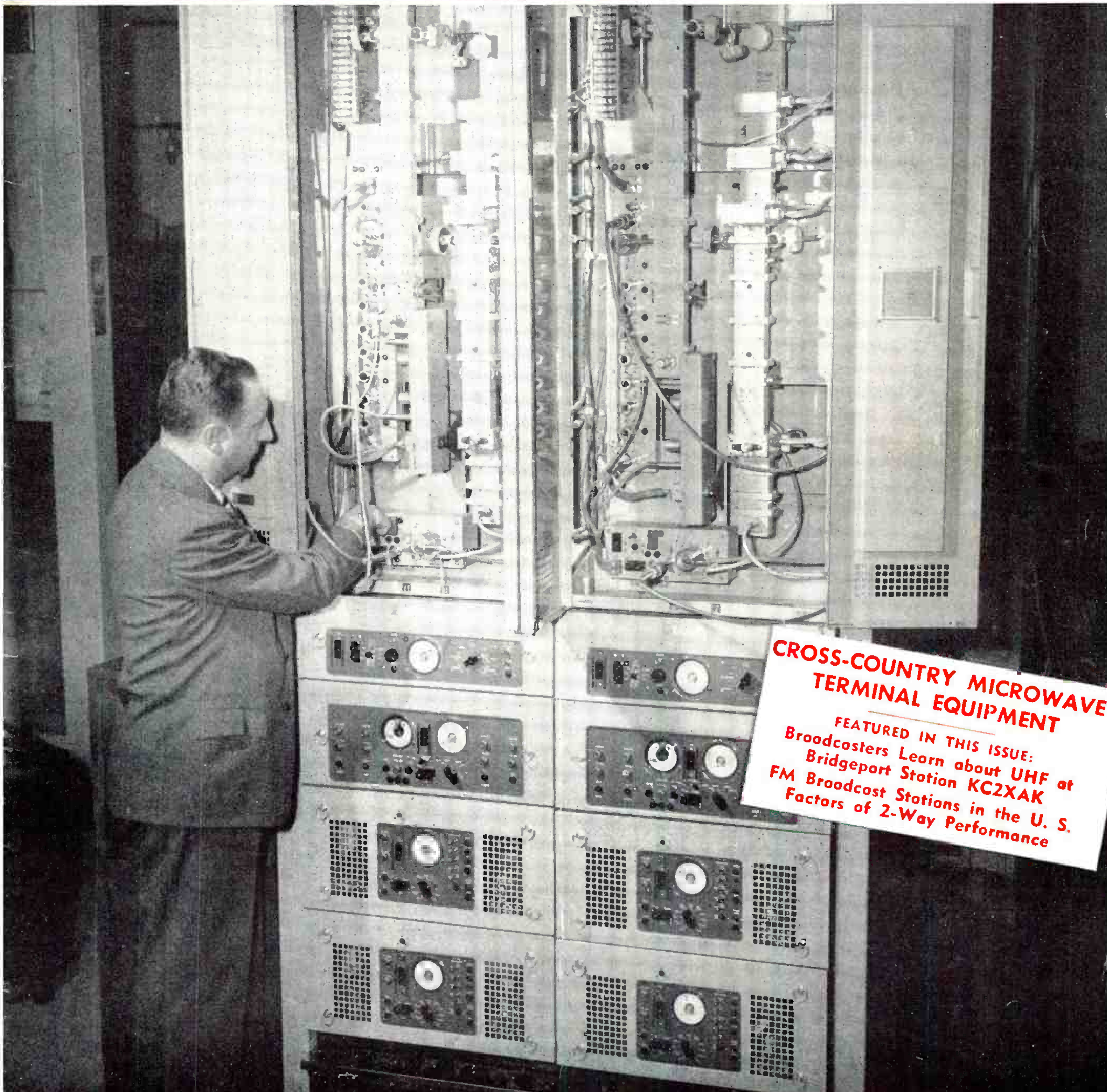
Sept. '51

# FM-TV RADIO COMMUNICATION

★★ Published by ★★
Milton B. Sleeper



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FEATURED IN THIS ISSUE:
Broadcasters Learn about UHF at Bridgeport Station KC2XAK
FM Broadcast Stations in the U. S.
Factors of 2-Way Performance

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# FM-TV RADIO COMMUNICATION

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CPA AUDIT

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


At first glance, the June production of 1,049,265 AM receivers is most impressive, because this is the greatest June volume since 1947. However, the breakdown into home, portable, and auto models discloses the fact that far more automobile radios were turned out than sets for home use. Since auto sets are sold to the car manufacturers, and installed as standard equipment, it can be assumed that the increase in this category is due to forced sale, rather than public demand. Anyway, this means work for servicemen and sales of replacement parts.

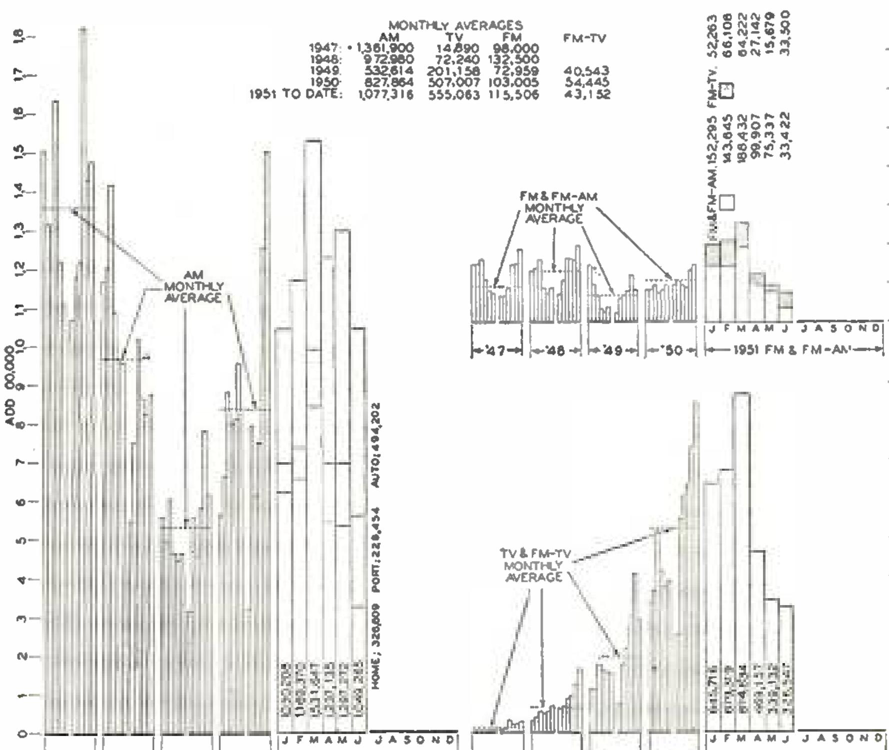
TV production continues to run below corresponding months of last year. Particularly significant is the RTMA report showing that June shipments to the dealers totaled only 160,308 units. Since 326,547 were manufactured, it can be assumed that something more than one-half of the sets went into factory warehouses for storage.

For the first 6 months of '51, TV production amounted to 3,334,505 sets but, according to RTMA, only 2,470,954 sets were shipped to dealers, indicating that warehouse stocks rose by some 863,000 TV units during that period. This supply will probably melt away rapidly when new stations go on the air next year. Meanwhile, with new models coming out at substantially lower prices, the dollar value of that inventory is shrinking. Net result is a serious squeeze on the smaller set manufacturers, some of whom will probably fold up this winter or in the spring.

Total TV set production in '51 will probably be well below the 1950 figure. RTMA's preliminary estimate for July is 116,000, and it looks as if the remaining months will not equal the same period last year.

FM production dropped sharply in June, although the average monthly figure is still well above last year. RCA has introduced a new model with a stage of tuned RF. This should prove a popular number, along with the Zenith and G-E sets. FM tuners for custom installations are not reported by RTMA, but demand has been high right through the summer, and production has probably equalled that of the complete cabinet models.

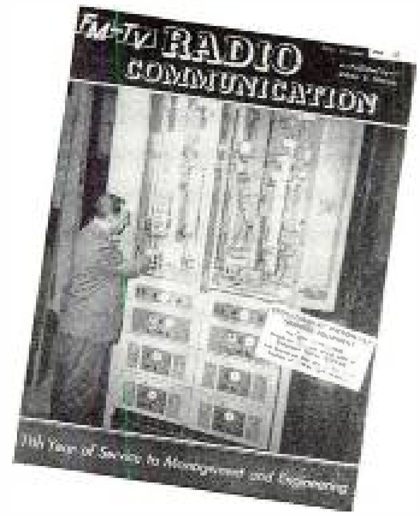
Picture tube sales to manufacturers amounted to 221,759 units, of which 86% were rectangular in shape, while 92% were 16 ins. or larger in size. Total value was $4,664.744.




*TV, FM, and AM set Production Barometer, prepared from RTMA figures*

### THIS MONTH'S COVER

The FM relay system now operated by AT & T between New York and San Francisco represents the most advanced application of microwave communication. Developed and manufactured by the coordinated efforts of engineers at Bell Laboratories and Western Electric, the equipment provides the degree of dependability dictated by telephone practice, and a quality of service such that there is no visible deterioration of TV signals passing through 107 stations. Part of the microwave terminal equipment at New York City is shown on this month's cover. Everything in this system is installed in duplicate.




# SPOT NEWS NOTES

**ITEMS AND COMMENTS, PERSONAL AND OTHERWISE, ABOUT PEOPLE AND COMPANIES CONCERNED WITH RADIO COMMUNICATIONS**

**Five-State FM Network:**

Is being studied by broadcasters in Alabama, North and South Carolina, Georgia, and Tennessee. There are more than 100 FM stations in that area.

**1,500-Ft. Tower Projected:**

Group of Oklahoma businessmen, including ex-Governor Roy Turner, is planning a 200-kw. TV station with a tower 1,500 ft. high, to provide virtually complete coverage of the state.

**New Appointments:**

Dr. Charles B. Jolliffe has been elected to the newly-created post of vice-president and technical director of RCA, and Dr. E. W. Engstrom has been elected vice president in charge of the RCA laboratories.

**Coast-to-Coast TV:**

First TV program service between New York and San Francisco, carrying the opening session of the Japanese Peace Treaty Conference on September 4, was highly successful. Reports from various parts of the Country indicated no deterioration of picture quality, as compared to reception of local stations. In that respect, the FM relay is distinctly superior to the coaxial cable, even on such relatively short distances as from New York to Washington.

**More Hours of FM Programs:**

Stations answering a questionnaire sent out by NARTB revealed that 27% are on the air 18 hours or more per day, 41% are on 12 to 18 hours, and 32% are on 6 to 11 hours. Also, 21% of the reporting stations carry separate programs on FM 90 to 100% of the time.

**J. Andrew White:**

Many old-timers in the radio business have wondered what happened to the editor of the *Wireless Age*, whose articles inspired their early interest in what came to be called *radio* in later years. Many of us remember him as the first to broadcast fights and baseball games. Less known is the fact that he founded CBS in 1927, and three years later sold his stock to William Paley. Today, he has a Tuesday midnight program on KNX Hollywood, and a very popular one, we hear.

**Shielded Leads:**

Highly flexible leads of low capacitance and RF losses, intended for laboratory use, are being manufactured by United Technical Laboratories, Morristown, N. J. A 3-ft. length, 9/32 in. in diameter, has a capacitance of 25 mmf.

**Field Tests of Color TV:**

About the first of October, RCA will start color demonstrations for the public at the Centre Theatre and at the RCA Exhibit Hall, New York City. Programs will be transmitted daily at 10:00 to 10:15 A.M. from KE2XJV, on the Empire State Building. In addition, there will be two closed-circuit programs between 2:15 and 4:00 P.M.

**Dr. Edward U. Condon:**

Appointed director of research and development for Corning Glass Works, Corning, N. Y. President Truman has accepted his resignation as Director of the National Bureau of Standards, effective September 30. Dr. Jesse T. Littleton, vice president and present director

*(Continued on page 7)*

## SPOT NEWS NOTES

*(Continued from page 6)*

of research and development, will become general technical adviser.

**Tape Development Laboratory:**

As a part of its long-range plan of expansion, Magnecord has established a new laboratory of 7,000 square feet, devoted to research on tape equipment. This activity will be headed by Otto C. Bixler, recently appointed director of engineering. He was previously associated with Airesearch and Western Electric.

**More TV Relay Service:**

A south-bound TV channel from Detroit to Toledo was opened by AT & T on September 5. In addition, 2-way TV program service was inaugurated on September 28 between New York City and San Francisco.

**Close-Tolerance Capacitors:**

A series of shielded, hermetically-sealed capacitors, intended for oscillator circuits, frequency standards, frequency meters, and similar applications, has been announced by Centralab, 900 E. Keefe Avenue, Milwaukee 1. Tolerances are plus or minus 1% up to 2,200 mmf., and 5% up to 6,000 mmf. All values are rated at 500 volts DC working voltage.

**New Address:**

Announcement from Dow Corning Corporation says: "We notified our customers, the water department, the telephone company, the paper boy, our ever-loving spouses, and the receptionist's boy friends. Now we'd like to pass the word on to your readers and our prospects that we have moved to 600 Fifth Avenue, New York 20." The note was signed by M. H. Langford, manager of the New York office.

**Base for Chromium Finish:**

To eliminate the use of nickel plating as a base for chromium, E. I. duPont de Nemours, Wilmington, Del., is making available information on the use of white brass alloy in place of nickel. The white brass is an 80-20 zinc-copper alloy, which is deposited electrically from a cyanide bath, using special brightening agents. Subsequently, articles are chromium plated in the usual manner.

**James B. Ferguson:**

Appointed chief engineer of Link Radio. He joined the company as a consultant in 1950, and was responsible for the current Link Expediter mobile equipment. He will be assisted by Frederick A.

*(Continued on page 8)*

## SPOT NEWS NOTES

*(Continued from page 7)*

Schaner, in charge of Government development; Harold Heimark, in charge of commercial development; and J. W. Campbell, in charge of engineering coordination and services.

**Camera Equipment:**

J. A. Maurer, Inc., Long Island City, N. Y., manufacturers of motion picture cameras widely used for television shows, has been awarded a $750,000 contract for P-2 cameras used in jet fighter aircraft. This camera was designed by John A. Maurer for the Air Material Command.

**IRE-RTMA Fall Meeting:**

Will be held this year at the King Edward Hotel, Toronto, October 29 to 31. Papers will deal principally with television equipment and color developments.

**Radio Research Facilities:**

A building of 40,000 square feet has been acquired by Belmont Radio Corporation, subsidiary of Raytheon, for research, engineering, and pilot production. William Garstang, recently named administrative director of engineering and research, will be in charge of this activity.

**IRE Mobile Radio Meeting:**

Two-day meeting at Hotel Sheraton, Chicago, October 25 and 26, will be devoted to mobile radio engineering problems. Papers will be delivered by G. C. Terrell, Workshop Associates; Messrs. Morris, Bond, and Byrne, Motorola; F. T. Budelman, Link Radio; A. A. MacDonald, Westinghouse; H. H. Davids, GE; M. R. Friedberg, Ward Products; R. H. McRoberts, U. S. CDA; D. W. Bodle, Bell Labs; J. S. Brown, Andrew; and H. K. Lawson. FCC Commissioner Webster will speak at the Thursday banquet, and Gen. J. D. O'Connell at the Friday luncheon. Further information can be obtained from E. S. Goebel, Motorola, Inc., 4545 Augusta Boulevard, Chicago 51.

**Inexpensive Method:**

Some tapes made in Europe for subsequent recording on discs manufactured here involve no cost for talent or studio. That's because the tape recorder is merely hooked up to the output of a good radio receiver.

**Nickel Shortage:**

Although the 229 million tubes were produced this year used only two-thirds as much nickel as went into 191 million tubes manufactured in the same period of 1950, RTMA predicts that, unless the

*(Concluded on page 9)*

## SPOT NEWS NOTES

*(Continued from page 8)*

current nickel allocation is increased, it will be necessary to cut tube production about October 15, and that by December 1 tube output will be down to 50% of the present level.

**UHF Television Performance:**

Attitude toward UHF has changed since the first report on TV reception from RCA-NBC station at Bridgeport. Engineering discussion at demonstration for broadcasters on September 12 confirmed, to a considerable extent, the thinking presented in RADIO COMMUNICATION last month under the title "After the Thaw: a Log Jam."

**Source of Competition:**

Photographic supply stores, particularly those aggressive merchandisers who obligingly extend professional discounts to all customers, are cutting themselves quite a slice of the tape recorder business. While they may be short on technical information and service, they are long on price promotion. Radio dealers and parts jobbers, particularly those specializing in hi-fi equipment, should watch this new competition.

**TV Picture Quality:**

It would seem that now, with TV set manufacturers being forced to *sell* their products for the first time, an improvement in picture quality would provide a major sales advantage. This could be obtained simply and inexpensively by incorporation of a circuit to insure perfect line interlace. Why this hasn't been done can be explained only by the manufacturers themselves, because the added cost would be negligible. There are exceptions — some sets have perfect interlace — but they are very few and generally in the custom-chassis field. For our money, line pairing is extremely annoying and the more inexcusable because it could be so easily prevented.

**What Next Dept.:**

One of the most recent applications of supervisory control and telemetering equipment is that of transmitting snow depth measurements from isolated points. These measurements are required in order to utilize efficiently the water stored as snow in watersheds.

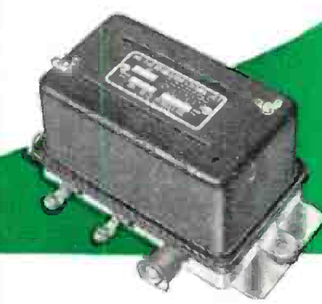
The thickness gauge, developed by the U. S. Weather Bureau, is composed of radioactive isotopes buried in the ground at a strategic point with a Geiger-Muller counter suspended overhead on a pole. Intensity of radiation reaching the counter varies inversely with the thickness of the snow. Motorola telemetering equipment is used.

# Leece-Neville

## ALTERNATOR SYSTEMS

**25 to 35 amperes with engine idling**

**MORE current output at ALL speeds**



### THE ANSWER TO YOUR BATTERY PROBLEMS

An inadequate generating system is the basic cause of battery troubles. Today's increasing load of accessories takes more current out of the battery than a conventional d.c. generator can put back in. Slow driving, long idling periods and short trips cut current output further. The result: heavy expenses for replacement and recharging of batteries, breakdown of equipment, lost man-hours. A costly, heavy-duty battery is no solution. The answer is replacement of the conventional d.c. generator with the revolutionary Leece-Neville AC-DC Alternator System.

### 25 TO 35 AMPERES IDLING

With engine idling, a conventional d.c. generator shows "discharge" on the ammeter. But the L-N Alternator under this condition is producing 25 to 35 amperes . . . enough current to operate accessories and charge the battery too. Furthermore, the Alternator delivers its full capacity at low engine speed and maintains full output at top speed.

### CONSTANT FIXED VOLTAGE

Variation in voltage shortens the life of electrical components and is often responsible for damage to the battery. The rugged, highly accurate L-N Regulator protects all electrical units by its sensitive control. Batteries stay fully charged with *no overcharging*. For the complete story of the L-N Regulator, write for special bulletin.

### PERFORMANCE PROVED

Since 1946, L-N Alternators have been producing more current on thousands of installations. Many units have run 100,000 to 400,000 miles and more!

There are Alternator Systems rated at 50 and 80 amps. for 6-volt systems; from 60 to 150 amps. for 12-volt systems.

For all the facts, send for the new, illustrated bulletin on the L-N Alternator System. The Leece-Neville Company, Cleveland 14, Ohio.

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**QUALITY ELECTRICAL EQUIPMENT**

# REPORT ON UHF-TV

## OFFICIAL ATTITUDE OF THE FCC TOWARD UHF TELEVISION, AS REFLECTED IN A SPEECH BY CHAIRMAN COY AT BRIDGEPORT UHF-TV DEMONSTRATION

SINCE December 30, 1949, Bridgeport UHF-TV station KC2XAK has been on the air, rebroadcasting programs picked up by microwave link from WNBT New York. This experimental station was planned to approximate as closely as possible a commercial outlet, even to the extent that the installation was laid out for operation with only two engineers in attendance. Receivers converted for UHF reception were placed in homes at various locations in the Bridgeport area, and extensive field tests were begun.

It is common knowledge that reports on this installation have been highly encouraging.[1] Yet, applicants for TV broadcasting licenses have consistently ignored the wide-open spaces of UHF and have deluged FCC offices with applications for VHF assignments, despite the fact that the FCC allocation plan provides for only 170 more VHF stations in 118 cities of 50,000 population or more.[2]

### Reason for the Meeting:

When 64 member-companies of RTMA demonstrated UHF converter units at Bridgeport last July, results were so impressive that a proposal was made to take UHF equipment to broadcasters around the country, so that they could see for themselves that "UHF is not the Antarctic of the radio spectrum." This was considered seriously, but was shown to be too expensive and time-consuming. Instead, RCA-NBC arranged a UHF seminar at Bridgeport for broadcasters and broadcast engineers.

On Sept. 12, the day of the meeting, FCC Chairman Wayne Coy was the principal speaker at a luncheon in the Hotel Barnum. This was followed by a comparative demonstration of reception on VHF channel 4 and UHF frequencies of 530 and 850 mc. Technical discussions were given by C. M. Sinnett, J. E. Young, and P. J. Herbst of RCA, and Raymond F. Guy of NBC.

### Effect of New Stations:

Frank Folsom, president of RCA, opened the meeting with a short speech, significant parts of which are quoted:

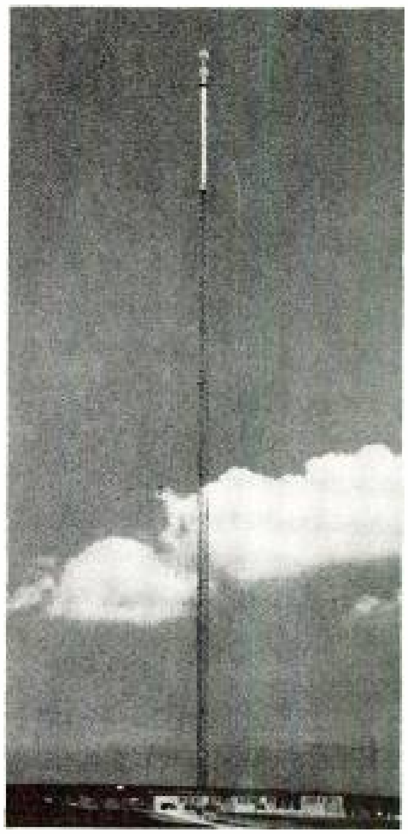
"We of RCA are happy to be showing you today the first television station in the United States to transmit, on an experimental basis, regular daily programs at ultra-high frequencies. This is a tremendous field we are working in. Television has been, and will continue to be, the nation's fastest-growing industry . . . I think it is big not just because of its sales potential but because, with television, we can see history happen. Last week, for example, we watched in our own living rooms as delegates of 52 nations participated in the Japanese Peace Treaty Conference . . . Yes, the opening of coast-to-coast television is a major step forward in the development of a nationwide television service.

"But when you come right down to it, the East-West microwave link is only part of the story. Another equally important chapter is yet to be told. And it will be headed with three simple letters — UHF.

"To you and me UHF stands for Ultra-High-Frequency . . . But to the American public it [means] something much more understandable . . . an opportunity for every community in America to enjoy the pleasures of television.

"In cold figures, the opening up of new . . . channels in the UHF band will shortly mean the addition of nearly 2,000 new television stations . . . Together with the new stations proposed for the present VHF band, this will mean the building of a nationwide television network of nearly 3,000 stations.

"I don't think that I am being overly optimistic when I predict that within a short time after these . . stations become realities, there could be 50 million television sets in the United States . . . nearly every community in America not only [having] television, but with station facilities that will permit them to originate their own programs."



**NEW BRITISH TV TOWER**

GREAT BRITAIN'S third television station, at Holme Moss, will begin operation on October 12. This site is close to Huddersfield in Yorkshire, at an elevation of 1,700 ft. The 750-ft. mast shown above is topped by a 2-bay antenna which handles effective radiated powers of 45 kw. video and 12 kw. sound. Programs transmitted will be the same as those from the Alexandra Palace and Sutton Coldfield stations, and will be carried to Holme Moss by coaxial cable.

### Necessity for UHF-TV:

Following Mr. Folsom's introductory remarks, FCC Chairman Wayne Coy took the floor. His speech was extemporaneous, and no stenographic transcript was made. However, because Mr. Coy's words were obviously of vital interest not only to broadcasters but to all sections of the industry, they will be reconstructed with as much detail as possible from notes made at the time.

First, Mr. Coy indicated that he wanted to convince station managers and their representatives of the very real advantages of UHF for television. If he could so convince them, he said, it would considerably shorten the time required to inaugurate nationwide television service.

So sold on UHF is he personally, Mr. Coy stated, that he would like to see all TV in the UHF range. In fact, he has proposed this, but has been outvoted by other members of the Commission. However, he is firmly convinced that the ultimate home of TV will be in the UHF band.

The reasons for this statement are apparent when the history of VHF-TV is reviewed, said Mr. Coy. Before the war, 18 VHF channels were allocated for television. In the 1945 reallocation, 5 of these were deleted for mobile services, while other such services were to share

[1] "Bridgeport UHF Test Results," by Raymond F. Guy, RADIO COMMUNICATION May, 1950.

[2] "After the TV Thaw—A Log Jam," by Roy Allison, RADIO COMMUNICATION August, 1951.

the remaining 13 channels with TV on a non-interfering basis. This proved impossible of accomplishment, so channel 1 was deleted and given to the mobile services for their exclusive use. Mr. Coy thought that this was not quite a fair settlement, and indicated that the needs of the mobile services are so pressing that this reallocation was not the final answer. Unless engineers can develop mobile radio equipment capable of operating on still narrower channels, he said, and do it quickly, television will have a vociferous opponent for VHF frequencies. He thought that such devices would probably not be available soon enough to relieve the increasing congestion in the mobile services.

Another reason for fostering UHF-TV, Mr. Coy said, is that it is manifestly impossible to have a truly competitive television service employing VHF alone. Originally, allocations were such as to provide at least 180-mile separations between stations on the same channel. Applications were so numerous that the FCC yielded to supposedly well-informed opinion and began making co-channel assignments at 150-mile intervals. The resulting interference caused the freeze which began in September, 1948, and is not yet ended. It is evident that 12 channels are not enough for a comprehensive and competitive TV broadcasting system.

The FCC, Chairman Coy stated, believes firmly in the efficacy of competition in building healthy and prosperous communication services. He cited the 2,300 audio broadcasting stations in the Country as an example of the results of this policy. By utilizing the UHF band, plus the present 12-channel, 72-mc. segment of the VHF band, almost 3,000 TV stations can be accommodated. This should provide adequate possibilities for healthy competition, not only among the stations themselves, but with the other forms of entertainment media. He also stressed that the FCC would be vigilant against the formation of monopolies in radio communication.

**Competition and Progress:**

Mr. Coy is convinced that comparative demonstrations of UHF and VHF performance have shown conclusively that manufacturers have enough technical know-how in both transmitter and receiver design for UHF, so that the FCC is now justified in allocating UHF for commercial television.

There is more room for improvement in UHF techniques — but this goes for VHF also, he remarked. There has been continuing progress in receiver design for the past 20 years. Much of this has been in the last 18 months, it will be noted, when manufacturers with large investments in tools for receiver fabrication have been confronted with the problem of extending receiver markets. This is, of course, beneficial to the public — but, he asked, why hadn't the public been considered before?

In its proposed initial allocations for UHF-TV, the FCC has taken into account manufacturing problems such as suppression of oscillator radiation and image response. Thus, it is planned to separate UHF stations in the same city by 6 channels. This should result in facilitating the design and production of satisfactory UHF receivers and converters, at lower prices. It should be noted that this plan of allocation was not for the benefit of the manufacturers, but for the public interest. By making receivers as inexpensive as possible, the expansion of TV service will be hastened considerably.

Mr. Coy said that he had never been able to understand why manufacturers have not shared this concern for the public, since good, inexpensive receivers will create wider markets. He doubted that any manufacturer had appeared during the recent allocations proceedings to seek wider spacing between UHF channel assignments. There was surprisingly little concern for the public's benefit among both broadcasters and manufacturers. As a rule, he said, broadcasters were interested in means to reduce interference, especially by reducing the number of licenses granted, but only after they had *their* licenses.

**Quality on UHF:**

The chairman was of the opinion that the quality of reception from the two Bridgeport UHF transmitters is excellent. Perhaps the performance is not quite equal to the best now obtainable on VHF, but it was evident that UHF is "not a lemon, as some have inferred." With respect to ignition interference, noise, and diathermy vulnerability, it is better than VHF. He said that in downtown New Haven, about 16 miles from the KC2XAK transmitter, reception was equal to that from the New Haven VHF station and suggested that all those too timid to venture into UHF should see this for themselves.

**Power Limitations:**

Mr. Coy pointed out that as frequency is increased, the 5,000-microvolt contour is extended further from the transmitting antenna. However, receiver input requirements increase disproportionately.

In order to equalize the coverage areas, a UHF station must have an effective radiated power 10 times that of a station in the lower VHF band, or 3 to 4 times the power of a high-band VHF station.

There are no limitations on maximum UHF power contemplated at present, he said. Power limitations will be necessary only when transmitters 10 times as powerful as present VHF transmitters are produced.

**Conclusion:**

Chairman Coy reiterated that the VHF channels are not adequate to provide a suitable competitive television system, or even a single outlet in each city of over 50,000 population. All the UHF band must be employed eventually. Of all present applicants for TV licenses, he said, two-thirds to three-fourths will have to accept UHF assignments or go without.

**Equipment Maintenance:**

At the conclusion of Chairman Coy's speech, Mr. Folsom introduced Dr. C. B. Jolliffe, vice-president and technical director of RCA. He spoke of the Corporation's research work on UHF, and said, in part, "Since December 30, 1949, we have operated this station on a regular schedule . . . And I'd like to point this out: the maintenance of this station has not been any more difficult or complicated than [that of] a standard VHF television station.

"The engineers of NBC and the RCA Service Company have made a careful survey of propagation and reception throughout the Bridgeport area, and recordings have been made at relatively great distances from the station. Our tests have showed that reception on UHF can be just as clear and stable as on VHF. In some instances, it is even better."

And it *was* better on the occasion of this demonstration. In the comparative tests that followed the talks, the two UHF receivers were unaffected, even with reduced signal inputs, by automobiles passing in the street below. On the other hand, the picture on the VHF set was occasionally broken by the ignition interference.

Differences in picture quality and resolution, if any, were not discernible a few feet away from the receivers. The converters employed were not much larger than a cigar box, and seemed to be fairly simple affairs.

**Broadcasters Must Act:**

This very impressive demonstration confirmed Mr. Coy's contention that broadcasters may, in their generally futile insistence upon entering TV via VHF channels, lose the opportunity to get in on the ground floor when the FCC begins issuing CP's again. As a matter of fact, if they delay too long they may find that all the UHF channels available in their localities have been applied for by less short-sighted individuals.

# FM STATIONS

## A LIST OF FM BROADCAST STATIONS, COMPILED FROM FILES OF THE FCC

Stations are listed alphabetically by cities and states.
An asterisk after name of city indicates that station is non-commercial educational.
Second column is frequency.
Third column is effective radiated power in kw.
Asterisk before call letters indicates construction permit.

### ARIZONA

| | | | |
|---|---|---|---|
| Phoenix* | B8.5 | .01* | KFCA |
| Thatcher* | 8B.1 | .01 | KGIA |

### ARKANSAS

| | | | |
|---|---|---|---|
| Blytheville | 96.1 | 21 | KLCN-FM |
| Conway | 97.7 | .97* | KOWN |
| Ft Smith | 94.9 | 14 | KFPW-FM |
| Ft Smith | 107.1 | .32* | KFSA-FM |
| Jonesboro | 101.9 | 8 | KBTM-FM |
| Little Rock | 95.9 | .39* | KVLC-FM |
| Silom Spgs | 105.7 | 2.6 | KUOA-FM |

### CALIFORNIA

| | | | |
|---|---|---|---|
| Alhambra | 107.1 | .37* | KSJW |
| Bakersfield | 94.1 | 9.8 | KERN-FM |
| Bakersfield | 92.5 | 4.7 | * KMAR |
| Berkeley | 104.9 | 1 | * KPFA |
| Berkeley | 102.9 | 6.8 | KRE-FM |
| Beverly Hls | 106.3 | 1 | * KSRT |
| Chico | 101.1 | 9.8 | KVCI |
| Eureka | 96.3 | 4.6 | KRED |
| Fresno | 101.9 | 7.4 | KARM-FM |
| Fresno | 97.9 | 7.3 | KMJ-FM |
| Fresno | 93.7 | 70 | * KRFM |
| Glendale | 101.9 | 9.9 | * KUTE |
| Hollywood | 94.7 | 5B | KFMV |
| Hollywood | 101.1 | 4.8 | KHJ-FM |
| Hollywood | 97.1 | 5B | KKLA |
| Hollywood | 93.1 | 59 | * KNX-FM |
| Inglewood | 92.7 | .38* | KEFM |
| Inglewood | 105.5 | .75* | KHOA-FM |
| Long Beach | 102.3 | 1 | * KFOX-FM |
| Long Beach* | 88.1 | .01 | KLON |
| Long Beach | 103.1 | .32* | KNOB |
| L Angeles | 95.5 | 3.8 | * KECA-FM |
| L Angeles | 104.3 | 8.8 | * KFAC-FM |
| L Angeles | 105.9 | 16 | * KFI-FM |
| L Angeles | 100.3 | 72 | * KMAU |
| L Angeles | 98.7 | 49 | * KMGM |
| L Angeles | 96.3 | 15 | KRKD-FM |
| L Angeles* | 91.5 | 2.9 | KUSC |
| Marysville | 99.9 | 4.7 | KMYC-FM |
| Merced | 97.5 | 8.9 | KVME |
| Modesto | 103.3 | 11 | KBEE |
| Modesto | 104.1 | 4.7 | * KTRB-FM |
| Oakland | 101.3 | 20 | KLX-FM |
| Oceanside* | 89.7 | .01 | KOEN |
| Ontario | 93.5 | .31 | KEDO |
| Pasadena | 98.3 | .33 | KWKW-FM |
| Redding | 103.9 | 1 | KVRE |
| Riverside | 97.5 | 20 | * KPOR |
| Sacramento | 96.1 | 11 | KCRA-FM |
| Sacramento | 96.9 | 5.4 | KFBK-FM |
| Sacramento | 107.9 | 12 | KXOA-FM |
| Salinas | 94.5 | 3.2 | KSNI |
| San Bruno | 100.5 | 250 | * KSBR |
| San Diego | 94.1 | 33 | KFSD-FM |
| San Diego* | 91.7 | 3.3 | * KSDS |
| San Diego | 104.7 | .96 | KWFM |
| S Francisco* | 91.7 | 1.2 | KALW |
| S Francisco | 103.7 | 44 | * KCBS-FM |
| S Francisco | 106.1 | 50 | KGO-FM |
| S Francisco | 97.3 | 10 | KGSF |
| S Francisco | 98.9 | 35 | KJBS-FM |
| S Francisco | 99.7 | 45 | * KNBC-FM |
| S Francisco | 96.5 | 44 | * KRON-FM |
| S Francisco | 94.9 | 16 | * KSFH |
| San Jose | 92.3 | 340 | * KRPO |
| San Jose | 95.3 | 1 | KSJO-FM |
| Santa Ana | 96.7 | 1 | KVOE-FM |
| S Monica* | 89.9 | .46 | KCRW |
| Sausalito | 102.1 | 33 | * KDFC |
| Stockton* | 91.3 | 3.4 | KCVN |
| Stockton | 92.9 | 1.4 | * KGDM-FM |

### COLORADO

| | | | |
|---|---|---|---|
| Denver | 97.3 | 21 | * KFEL-FM |
| Denver | 94.1 | 5.3 | KLZ-FM |
| Denver | 95.7 | 43 | * KOA-FM |

### CONNECTICUT

| | | | |
|---|---|---|---|
| Greenwich | 95.9 | .46* | WGCH |
| Hartford | 93.7 | 7 | WDRC-FM |
| Hartford | 96.5 | B | WTIC-FM |
| Meriden | 95.7 | 7 | WMMW-FM |
| N Britain | 103.7 | 20 | WFHA |
| New Haven | 95.1 | 20 | * WAVZ-FM |
| New Haven | 100.7 | 20 | * WBIB |
| New Haven | 92.1 | .87* | WELI-FM |
| New Haven | 99.1 | 19 | WNCH-FM |
| Stamford | 96.7 | .65 | WSTC-FM |

### DELAWARE

| | | | |
|---|---|---|---|
| Georget'n | 101.5 | 20 | * WJWL-FM |
| Wilmington | 96.1 | 20 | * WAMS-FM |
| Wilmington | 93.7 | 20 | * WDEL-FM |

### DISTRICT OF COLUMBIA

| | | | |
|---|---|---|---|
| Washingtn | 97.1 | 15 | * WASH |
| Washingtn | 99.5 | 20 | WCFM |
| Washingtn | 107.3 | 20 | WMAL-FM |
| Washingtn | 101.1 | 20 | WOL-FM |
| Washingtn | 103.5 | 19 | * WQQW-FM |
| Washingtn | 93.9 | 20 | WRC-FM |
| Washingtn | 96.3 | 20 | WTOP-FM |
| Washingtn | 9B.7 | 20 | WWDC-FM |

### FLORIDA

| | | | |
|---|---|---|---|
| Daytona Bch | 94.5 | 8.5 | WNDB-FM |
| Ft Laudrdle | 106.5 | 9.2 | * WGOR |
| Gainesville | 104.1 | 12 | WRUF-FM |
| Jacksonville | 95.1 | 11.5 | WJAX-FM |
| Jacksonville | 96.9 | 32 | WJHP-FM |
| Jacksonville | 96.1 | 63 | WMBR-FM |
| Lakeland* | 88.1 | .01* | WFSI |
| Miami | 96.3 | 27 | * WGBS-FM |
| Miami | 97.3 | 53 | * WIOD-FM |
| Miami | 94.9 | 60 | WQAM-FM |
| Miami* | 91.7 | .40 | WTHS |
| Miami | 101.5 | 8.5 | WWPB-FM |
| Miami Beach | 93.1 | 285 | * WKAT-FM |
| Miami Beach | 93.9 | 13 | WLRD |
| Orlando | 92.3 | 34 | * WDBO-FM |
| Orlando | 96.5 | 59 | WHOO-FM |
| Palatka | 98.3 | .42* | WWPF-FM |
| Palm Beach | 97.9 | 22 | WWPG-FM |
| St Petrsbrg | 97.9 | 16 | * WMLD |
| St Petrsbrg | 102.5 | 37 | WTSP-FM |
| Tallahassee | 103.9 | .71 | WCSP |
| Tampa | 105.7 | 26 | * WDAE-FM |
| Tampa | 93.3 | 53 | WFLA-FM |

### GEORGIA

| | | | |
|---|---|---|---|
| Athens | 99.5 | 4.4 | WGAU-FM |
| Atlanta* | 90.1 | .40 | WABE |
| Atlanta | 103.3 | 50 | * WAGA-FM |
| Atlanta | 97.5 | 44 | WATL-FM |
| Atlanta | 95.5 | 14 | * WBGE-FM |
| Atlanta | 94.1 | 345 | * WGST-FM |
| Atlanta | 98.5 | 52 | * WSB-FM |
| Cedartown | 96.1 | 5.5 | WGAA-FM |
| Columbus | 107.9 | 10 | * WDAK-FM |
| Columbus | 95.1 | 9 | WGBA-FM |
| Columbus | 93.3 | 46 | * WRBL-FM |
| Gainesville | 103.9 | .30 | WDUN-FM |
| Lagrange | 104.1 | 1.3 | * WLAG-FM |
| Macon | 100.7 | 15 | WBML-FM |
| Macon | 99.1 | 3 | * WMAZ-FM |
| Macon | 96.9 | 41 | WNEX-FM |
| Newnan | 96.7 | .33* | WCOH-FM |
| Rome | 106.5 | 1.1 | * WRGA-FM |
| Savannah | 94.3 | .0B* | WDAR-FM |
| Savannah | 100.3 | 15 | WSAV-FM |
| Savannah | 97.3 | 43 | * WTOC-FM |
| Toccoa | 106.1 | 10 | WLET-FM |
| Valdosta | 92.5 | 7 | WGOV-FM |

### IDAHO

| | | | |
|---|---|---|---|
| Meridian | 101.9 | 2.5 | KFXD-FM |
| Pocatello | 96.5 | 1.8 | WSEI-FM |
| Twin Falls | 99.7 | 3 | KTFI-FM |

### ILLINOIS

| | | | |
|---|---|---|---|
| Alton | 99.9 | 9.1 | WOKZ-FM |
| Bloomingtn | 101.5 | 15 | * WJBC-FM |
| Blue Island | 94.3 | 1 | * WRBI |
| Canton | 100.9 | .65 | WBYS-FM |
| Carmi | 97.3 | 11 | * |
| Centralia | 96.5 | 2.4 | WCNT-FM |
| Champaign | 97.5 | 27 | WDWS-FM |
| Chicago | 93.9 | 28 | WAAF-FM |
| Chicago | 97.1 | 13 | WBBM-FM |
| Chicago* | 91.5 | 15 | WBEZ |
| Chicago | 96.3 | 19 | * WBIK |
| Chicago | 99.5 | 30 | WEFM |
| Chicago | 97.9 | 15 | WEHS |
| Chicago | 94.7 | 25 | WENR-FM |
| Chicago | 93.1 | 29 | WFJL |
| Chicago | 100.3 | 33 | WFMF |
| Chicago | 98.7 | 35 | WGNB |
| Chicago | 101.1 | 24 | WMAQ-FM |
| Chicago | 95.5 | 46 | WMBI-FM |
| Chicago | 102.7 | 40 | WMOR |
| Chicago | 105.9 | 9.3 | * WOAK |
| Chicago | 101.9 | 30 | * WXRT |
| Chicago Hts | 95.9 | .25 | WCHI |
| Decatur | 102.1 | 31 | WSOY-FM |
| E St Louis | 102.5 | 55 | WTMV-FM |
| Elgin* | 88.1 | .01 | WEPS |
| Elmwd Pk | 107.1 | .95 | WLEY |
| Evanston* | B8.5 | .01* | WDLJ |
| Evanston | 105.1 | 36 | WEAW |
| Evanston* | 89.3 | .01 | WNUR |
| Freeport | 102.5 | 9 | WFJS |
| Harrisburg | 99.9 | 4.2 | WEBQ-FM |
| Herrin | 98.5 | 20 | * WJPF-FM |
| Jacksonv'le | 100.5 | 7.3 | WLDS-FM |
| LaSlle-Peru | 106.9 | 13 | * WFMX |
| Mattoon | 96.9 | 23 | * WLBH-FM |
| Mt Vernon | 94.1 | 15 | WMIX-FM |
| Oak Park | 102.3 | 1 | * WOPA-FM |
| Peoria | 92.5 | 16 | WMBD-FM |
| Quincy | 105.1 | 8.9 | WQDI-FM |
| Quincy | 99.5 | 53 | WTAD-FM |
| Rockford | 97.5 | 16 | WROK-FM |
| Rock Island | 98.9 | 37 | WHBF-FM |
| Springfield | 102.9 | 25 | WCVS-FM |
| Springfield | 103.7 | 6.7 | WTAX-FM |
| St Charles | 106.3 | .23 | WEXI |
| Urbana* | 91.7 | .10 | WIUC |
| Urbana | 103.3 | 2.4 | WKID-FM |
| Waukegan | 106.7 | 12 | WKRS |
| Woodstock | 92.1 | .83 | WILA |

### INDIANA

| | | | |
|---|---|---|---|
| Anderson | 106.3 | .35 | WCBC-FM |
| Blmington* | 90.9 | 33 | * WFIU |
| Columbus | 93.7 | 71 | WCSI |
| Connersvle | 100.3 | 9.8 | WCNB-FM |
| Crwfrdsvle | 102.9 | 13 | WFMU |
| Elkhart | 100.7 | 33 | WTRC-FM |
| Evansville | 104.1 | 19 | WIKY-FM |
| Evansville | 94.5 | 20 | WMLL |
| Evansville* | 91.5 | 1.9* | |
| Ft Wayne | 106.1 | 24 | WKJG-FM |
| Ft Wayne | 96.1 | 16.5 | WOWO-FM |
| Greencstle* | 91.7 | .01 | WGRE |
| Hammond | 92.3 | 9.3 | WJIZ |
| Huntington* | 88.1 | .01 | WVSH |
| Indianaplis* | 91.9 | .82* | WAJC |
| Lafayette | 95.1 | 12 | WFAM |
| Marion | 106.9 | 34 | WMRI |
| Michigan Cy | 93.5 | 1 | WIMS-FM |
| Muncie | 104.1 | 7.4 | WMUN |
| Muncie* | 91.5 | .01* | WWHI |
| N Albany* | B8.1 | .01 | WNAS |
| New Castle | 102.5 | 4 | WCTW |
| Shelbyville | 101.3 | 4.7 | WSRK |
| Terre Haute | 101.1 | 20 | WBOW-FM |
| Terre Haute | 99.9 | 7.4 | WTHI-FM |
| Warsaw | 107.3 | 34 | WRSW |
| Washingtn | 106.5 | 14 | WFML |

### IOWA

| | | | |
|---|---|---|---|
| Ames | 95.5 | 4.3 | * KASI-FM |
| Ames* | 90.1 | 15.5 | WOI-FM |
| Boone | 99.3 | .31* | KFGQ-FM |
| Burlington | 92.9 | 52 | KBUR-FM |
| Cdr Rapids | 96.9 | 50 | KCRK |
| Clinton | 96.1 | 13 | KROS-FM |
| Council Blfs | 96.1 | 9.3* | KFMX |
| Davenport | 103.7 | 47 | WOC-FM |
| Des Moines | 94.1 | 260 | * KCBC-FM |
| Des Moines | 104.5 | 275 | * KRNT-FM |
| Des Moines | 97.3 | 15 | KSO-FM |
| Des Moines | 100.3 | 400 | * WHO-FM |
| Dubuque | 100.5 | 45 | KDTH-FM |
| Dubuque | 103.3 | 15 | WDBQ |
| Ft Dodge | 102.7 | 10 | KFMY |
| Iowa City* | 91.7 | 16.5 | KSUI |
| Keokuk | 102.7 | 3.7 | KOKX-FM |
| Mason City | 101.1 | 16 | KGLO-FM |
| Muscatine | 99.7 | 9.3 | * KWPC-FM |
| Sioux City | 94.9 | 360 | * KSCJ-FM |
| Storm Lake | 101.5 | 8.9 | KAYL-FM |
| Waterloo | 105.7 | 17 | * KXEL-FM |

### KANSAS

| | | | |
|---|---|---|---|
| Grant Twnsp | 94.5 | 40 | KIMV |
| Hutchinson | 93.1 | 1.5 | * KWBW-FM |
| McPherson | 103.1 | .16* | KNEX-FM |
| Wichita | 100.3 | 11 | KFH-FM |
| Wichita* | 89.1 | .01 | KMUW |

### KENTUCKY

| | | | |
|---|---|---|---|
| Ashland | 93.7 | 4.1 | WCMI-FM |
| Bwlng Grn | 101.1 | 8.4 | WBON |
| Henderson | 99.5 | 20 | WSON-FM |
| Hopkinsvle | 98.7 | 8.7 | WHOP-FM |
| Lexington* | 91.3 | 2.3 | WBKY |
| Lexington | 94.5 | 2.9 | * WLAP-FM |
| Louisville | 100.7 | 30 | WBOX |
| Louisville* | B9.3 | .01 | WFPL |
| Louisville | 99.7 | 24 | WHAS-FM |
| Louisville | 95.1 | 17 | WRXW |
| Louisville* | 90.3 | .01 | WSDX |
| Madisonvle | 103.1 | 1 | WFMW-FM |
| Owensboro | 92.5 | 60 | WOMI-FM |
| Owensboro | 96.1 | 45 | WVJS-FM |
| Paducah | 93.3 | 32 | WKYC |
| Paducah | 96.9 | 17 | WPAD-FM |

### LOUISIANA

| | | | |
|---|---|---|---|
| Alexandria | 96.9 | 11 | KALB-FM |
| Alexandria | 99.7 | 4.7 | KVOB-FM |
| Baton Rge | 104.3 | 3.2 | WAFB-FM |
| Baton Rge | 98.1 | 7.6 | WBRL |
| Baton Rge | 101.1 | 3 | * WLCS-FM |
| Baton Rge* | 91.7 | 1.B | WLSU |
| Lafayette | 96.1 | 15 | KVOL-FM |
| Monroe | 104.1 | 17 | * KMFM |
| N Orleans* | 89.3 | .01 | WBEH |
| N Orleans | 105.3 | 156 | * WDSU-FM |
| N Orleans | 107.5 | B.6 | * WJBW-FM |
| N Orleans | 97.1 | 61 | * WRCM |
| N Orleans | 102.7 | 55 | WSMB-FM |
| N Orleans | 95.7 | 55 | WTPS-FM |
| N Orleans | 100.3 | 12 | * WWLH |
| Shreveport | 101.1 | 11 | * KRMD-FM |
| Shreveport | 94.5 | 13 | * KWKH-FM |

### MAINE

| | | | |
|---|---|---|---|
| Bangor | 93.1 | 11 | WGUY-FM |
| Lewiston | 93.9 | 13 | WCOU-FM |

### MARYLAND

| | | | |
|---|---|---|---|
| Annapolis | 99.1 | 17 | WNAV-FM |
| Baltimore | 95.5 | 20 | * WBAL-FM |
| Baltimore | 102.7 | 20 | WCAO-FM |
| Baltimore | 93.1 | 15 | * WCBM-FM |
| Baltimore | 104.3 | 20 | WITH-FM |
| Baltimore | 106.7 | 20 | * WKRE |
| Baltimore | 94.7 | 20 | WMCP |
| Bethesda | 106.3 | .50* | WBCC-FM |
| Bradbuy Hts | 96.7 | .42 | WBUZ |
| Cumberlnd | 102.9 | 2.5 | * WCUM-FM |
| Cumberlnd | 106.9 | 2.5 | * WTBO-FM |
| Frederick | 99.9 | 2 | * WFMD-FM |
| Hagerstwn | 104.7 | 1.5 | WJEJ-FM |
| Salisbury | 97.5 | 12 | WBOC-FM |
| Silver Sprg | 102.3 | .44* | WGAY-FM |
| Silver Sprg | 95.9 | .59* | WOOK-FM |

### MASSACHUSETTS

| | | | |
|---|---|---|---|
| Boston* | 90.9 | .3B. | WBUR |
| Boston | 92.9 | 20 | WBZ-FM |
| Boston | 100.7 | 20 | WCOP-FM |
| Boston | 103.3 | 20 | WEEI-FM |
| Boston* | 88.1 | .01 | WERS |
| Boston* | 89.7 | 20 | * WGBH |
| Boston | 94.5 | 20 | WHDH-FM |
| Boston | 98.5 | 29 | * WNAC-FM |
| Brockton | 97.7 | .80 | WBET-FM |
| Cambridge | 96.9 | 5 | * WXHR |
| Chicopee | 100.3 | 3.2 | * WACE-FM |
| Greenfield | 98.3 | 1 | WHAI-FM |
| Haverhill | 92.5 | 20 | WHAV-FM |
| Holyoke | 93.1 | 3.2 | WHYN-FM |
| Lawrence | 93.7 | 20 | WLAW-FM |
| Lowell | 99.5 | 12 | WLLH-FM |
| Lynn | 105.5 | .52 | WLYN-FM |
| N Bedford | 97.3 | 20 | WBSM-FM |
| N Bedford | 98.1 | 20 | WFMR |
| Paxton | 99.1 | 5 | * WGTR |
| Pittsfield | 94.3 | 1 | WBEC-FM |
| Springfield | 97.1 | 20 | WBZA-FM |
| Soringfield | 94.7 | 3.2 | WMAS-FM |
| Springfield | 101.9 | 10 | * WSFL-FM |
| Springfield | 97.9 | 13 | WSPR-FM |
| W Yarmouth | 94.3 | 1 | WOCB-FM |
| Worcester | 96.1 | 10 | WTAG-FM |

### MICHIGAN

| | | | |
|---|---|---|---|
| Ann Arbor | 9B.7 | 2.2 | WPAG-FM |
| Ann Arbor* | 91.7 | 44 | WUOM |
| Battle Crk | 102.1 | 45 | WELL-FM |
| Bay City | 96.1 | 41 | WBCM-FM |
| Benton Hrbr | 99.9 | 9.2 | WHFB-FM |
| Dearborn | 100.3 | 7.7 | * WKMH-FM |
| Detroit | 101.9 | 52 | WDET-FM |
| Detroit* | 90.9 | 2 | WDTR |
| Detroit | 93.1 | 30 | KJBK-FM |
| Detroit | 97.9 | 4.3 | WJLB-FM |
| Detroit | 96.3 | 24 | * WJR-FM |
| Detroit | 97.1 | 48 | WWJ-FM |
| Detroit | 101.1 | 30 | WXYZ-FM |
| E Lansing* | 90.5 | 9.7 | WKAR-FM |
| Flint | 107.1 | .40 | WAJL |
| Grd Rapids | 92.5 | 10.5 | WFRS |
| Grd Rapids | 93.7 | 550 | * WJEF-FM |
| Grd Rapids | 96.9 | 50 | * WLAV-FM |
| Kalamazoo* | 91.1 | .40* | WMCR |
| Mt Clemnts | 106.3 | .34 | WMLN |
| Muskegon | 106.5 | 4.7 | WKBZ-FM |
| Oak Park | 95.5 | 20 | WLDM |
| Owosso | 103.1 | 1 | WOAP-FM |
| Pontiac | 99.5 | 20 | * WCAR-FM |
| Port Huron | 99.1 | 22 | WTTH-FM |
| Royal Oak | 104.3 | 18 | WEXL-FM |
| Saginaw | 98.1 | 1.7 | WSAM-FM |
| Summit Twp | 92.3 | 16 | WIBM-FM |
| Wyandotte | 103.1 | 1 | WJJW |

### MINNESOTA

| | | | |
|---|---|---|---|
| Duluth | 92.3 | 62 | WEBC-FM |
| Mankato | 103.5 | 47 | KYSM-FM |
| Minneaplis | 97.1 | 11 | * WTCN-FM |
| Minneaplis | 105.9 | 5.3 | WTIS-FM |
| Minneaplis* | 91.7 | 4.4 | * KUOM-FM |
| Northfield | 95.7 | 49 | * WCAL-FM |
| St Cloud | 104.7 | 50 | KFAM-FM |
| St Paul | 102.1 | 57 | * KSTP-FM |
| St Paul | 99.5 | 90 | * WMIN-FM |
| St Paul* | 89.1 | .01 | WNOV |
| Winona | 97.5 | 55 | KWNO-FM |

### MISSISSIPPI

| | | | |
|---|---|---|---|
| Greenville | 101.9 | 19 | WJPR-FM |
| Gulfport | 101.5 | 3 | WGCM-FM |
| Hattiesburg | 97.9 | 2 | * WFOR-FM |
| Jackson | 102.9 | 50 | WJDX-FM |
| Meridian* | BB.1 | .01* | WMMI |
| Meridian | 98.5 | 3.6* | WMOX-FM |

### MISSOURI

| | | | |
|---|---|---|---|
| Cp Girard'u | 95.7 | B | * KFVS-FM |
| Cp Girard'u | 97.7 | .29* | KGMO |

| | | | |
|---|---|---|---|
| Clayton | 99.1 | 58 | * KFUO-FM |
| Farmington | 100.1 | .30 | KREI-FM |
| Jefferson Cy | 98.5 | 9 | KWOS-FM |
| Joplin | 96.1 | 70 | WMBH-FM |
| Kansas City | 94.9 | 54 | KCMO-FM |
| Kansas City | 98.1 | 9.7 | KOZY |
| Kennett | 98.9 | 6.9 | KBOA-FM |
| Poplar Bluff | 94.5 | 16 | KWOC-FM |
| Sedalia | 99.7 | 15 | KDRO-FM |
| Springfield | 94.7 | 11 | KTTS-FM |
| St Louis* | 91.5 | 12 | KSLH |
| St Louis | 93.7 | 71 | KXOK-FM |

**NEBRASKA**

| | | | |
|---|---|---|---|
| Columbus | 101.5 | 6.9* | KJSK-FM |
| Lincoln | 102.9 | 22 | KFOR-FM |
| Omaha | 98.7 | 8.7 | KBON-FM |

**NEVADA**

| | | | |
|---|---|---|---|
| Las Vegas | 103.9 | .36 | KENO-FM |

**NEW HAMPSHIRE**

| | | | |
|---|---|---|---|
| Claremont | 106.1 | 1.5 | WTSV-FM |
| Manchester | 100.1 | 1 | WKBR-FM |
| Manchester | 95.7 | 3.3 | WMUR-FM |
| Nashua | 106.3 | 1 | WOTW-FM |

**NEW JERSEY**

| | | | |
|---|---|---|---|
| Alpine | 93.1 | 6 | WFMN |
| Asbury Pk | 94.3 | 1 | WJLK-FM |
| Atlantic Cy | 100.7 | 14 | * WBAB-FM |
| Atlantic Cy | 98.5 | 15 | WFPG-FM |
| Bridgeton | 98.9 | 9 | WSNJ-FM |
| Elizabeth | 96.7 | 1 | WPOE |
| Newark | 94.7 | 13.5 | WAAT-FM |
| Newark* | 91.1 | 2.5 | WBGO |
| Newark | 102.7 | 20 | * WNJR-FM |
| N Brunsw'ck | 98.3 | 1 | WCTC-FM |
| N Brunsw'ck | 93.5 | 1 | WDHN |
| Paterson | 103.5 | 17 | WPAT-FM |
| Plainfield | 103.9 | 1 | WXNJ |
| So Orange* | 89.5 | 2 | WSOU |
| Trenton | 97.5 | 14 | WTOA |

**NEW MEXICO**

| | | | |
|---|---|---|---|
| Albuqrque* | 89.1 | .35 | KANW |

**NEW YORK**

| | | | |
|---|---|---|---|
| Albany | 93.9 | 2.1 | * WROW-FM |
| Auburn | 96.1 | 18 | WMBO-FM |
| Alleghany | 95.7 | 43 | WHDL-FM |
| Binghamtn | 92.7 | .33* | WINR-FM |
| Binghamtn | 100.5 | 12 | WNBF-FM |
| Brooklyn | 105.9 | 19 | * WBRO |
| Brooklyn* | 91.5 | 20 | WNYE |
| Buffalo | 106.5 | 105 | * WBEN-FM |
| Buffalo | 92.9 | 48 | WBNY-FM |
| Buffalo | 104.1 | 7.7 | * WWOL-FM |
| Buffalo | 103.3 | 4.6 | * WXRC |
| Cherry Vly | 101.9 | 1.4 | WVCV |
| Coram | 97.5 | 15 | * WFSS |
| Corning | 106.1 | 4.2 | WCLI-FM |
| Cortland | 99.9 | 14 | WKRT-FM |
| DeRytr Twp | 105.1 | 1.3 | WVCN |
| Endicott | 101.7 | .54 | WENE-FM |
| Floral Pk* | 90.3 | .35 | WSHS |
| Hempstead | 98.3 | 1 | WHLI-FM |
| Hornell | 105.3 | 8.3 | WWHG-FM |
| Ithaca | 97.3 | 40 | WHCU-FM |
| Ithaca* | 91.7 | .01 | WITJ |
| Jamestown | 93.3 | 9.5 | WJTN-FM |
| Lockport | 99.3 | .75 | WUSJ-FM |
| Massena | 105.3 | 13 | WMSA-FM |
| N Rochelle | 93.5 | 1 | * WGNR-FM |
| New York | 99.5 | 18 | WABF |
| New York | 106.7 | 10 | * WALK |
| New York | 101.1 | 5.8 | WCBS-FM |
| New York | 107.5 | 20 | * WEVD-FM |
| New York | 104.3 | 17 | WFDR |
| New York* | 90.7 | 3.5 | WFUV |
| New York | 101.9 | 10 | WGHF |
| New York | 95.5 | 6.5 | * WJZ-FM |
| New York | 92.3 | 11 | WMCA-FM |
| New York | 100.3 | 18 | WMGM-FM |
| New York | 97.1 | 1.6 | WNBC-FM |
| New York | 93.9 | 18 | WNYC-FM |
| New York | 98.7 | 3.4 | WOR-FM |
| New York | 96.3 | 11 | WQXR-FM |
| Niagara Fls | 98.5 | 46 | WHLD-FM |
| Ogdensbrg | 106.1 | 14 | * WSLB-FM |
| Oswego | 104.7 | 3 | WOPT-FM |
| Pghkeepsie | 104.7 | 2.3 | WHVA |
| Rochester | 98.9 | 20 | WHFM |
| Rochester | 97.9 | 7.7 | WRNY-FM |
| Schenectdy | 101.1 | 3.5 | WBCA |
| Schenectdy | 99.5 | 6 | WGFM |
| S Bristl Twp | 95.1 | 1.3 | WVBT |
| Springvlle* | 88.1 | .01* | WSPE |
| Syracuse* | 88.1 | .69* | WAER |
| Syracuse | 102.5 | 8.5 | WNDR-FM |
| Syracuse | 94.5 | 9 | WSYR-FM |
| Troy* | 91.3 | .46 | WEVR |
| Troy | 92.3 | 5.4 | WFLY |
| Troy | 102.7 | 3.5 | WTRI |
| Utica | 96.9 | 9 | WIBX-FM |
| Utica | 105.7 | 4.3 | WRUN-FM |
| Watertown | 100.5 | 14 | WWNY-FM |
| Wethersfld | 107.7 | 1.3 | WFNF |
| White Plns | 103.9 | .12 | WFAS-FM |

**NORTH CAROLINA**

| | | | |
|---|---|---|---|
| Asheboro | 92.3 | 10 | WGWR-FM |
| Asheville | 104.3 | 9.2 | WLOS-FM |
| Burlington | 101.1 | 34 | * WBBB-FM |
| Burlington | 93.9 | 2.8 | * WFNS-FM |
| Charlotte | 107.7 | 7.7 | * WAYS-FM |
| Charlotte | 99.9 | 277 | * WBT-FM |
| Charlotte | 104.7 | 50 | WIST |
| Charlotte | 103.5 | 38 | WSOC-FM |
| Durham | 105.1 | 36 | WDNC-FM |
| Elkin | 100.9 | .35 | WIFM |
| Fayetteville | 98.1 | 12 | WFNC-FM |
| Forest City | 93.3 | 1.5 | WBBO-FM |
| Gastonia | 101.9 | 11 | WGNC-FM |
| Goldsboro | 93.3 | 35 | WEQR |
| Goldsboro | 105.5 | .41* | WFMC |
| Greensboro | 97.3 | 23 | WFMY |
| Greensboro | 100.3 | 37 | WGBG-FM |
| Greensboro* | 89.9 | .01 | WGPS |
| Henderson | 92.5 | 9 | WHNC-FM |
| Hickory | 102.9 | 210 | WHKY-FM |
| High Point | 95.5 | 37 | WHPE-FM |
| High Point* | 89.3 | .01 | WHPS |
| High Point | 99.5 | 38 | WMFR-FM |
| Laurinburg | 96.5 | 8.8 | WEWO-FM |
| Leaksville | 92.7 | .82 | WLOE-FM |
| Lexington | 94.3 | .30 | WBUY-FM |
| Marion | 106.9 | 325 | WMIT |
| Mayodan | 93.5 | .38* | WFMB |
| Raleigh | 96.1 | 25 | WNAO-FM |
| Raleigh | 94.7 | 15 | WPTF-FM |
| Raleigh | 101.5 | 54 | WRAL-FM |
| Reidsville | 102.1 | 1.6 | WREV-FM |
| Roanke Rpds | 98.5 | 16 | WCBT-FM |
| Rocky Mt | 100.7 | 33 | WFMA |
| Rocky Mt | 92.1 | .27 | WEED-FM |
| Salisbury | 106.5 | 20 | WSTP-FM |
| Sanford | 103.1 | .33* | WSNS |
| Sanford | 105.5 | .49* | WWGP-FM |
| Shelby | 96.1 | 2.6 | WOHS-FM |
| Statesville | 105.7 | 2.4 | WSIC-FM |
| Thomasville | 98.3 | .45 | WTNC-FM |
| Wilmington | 96.3 | 13 | * WMFD-FM |
| Winstn-Slm | 93.1 | 34 | WAIR-FM |
| Wnstn-Slm | 104.1 | 48 | WSJS-FM |

**OHIO**

| | | | |
|---|---|---|---|
| Akron | 97.5 | 15 | WAKR-FM |
| Alliance | 101.7 | 1 | WFAH |
| Ashland | 101.3 | 10 | WATG |
| Ashtabula | 103.7 | 52 | WICA-FM |
| Athens* | 88.1 | .01 | WOUI |
| Bellaire | 100.5 | 20 | WTRF-FM |
| Canton | 92.5 | 14 | * WAND-FM |
| Canton | 94.9 | 1.7 | WCMW-FM |
| Canton | 94.1 | 25 | WHBC-FM |
| Cincinnati | 105.1 | 10 | WCPO-FM |
| Cincinnati | 101.9 | 13 | WKRC-FM |
| Cincinnati | 101.1 | 9 | WLWA |
| Cincinnati | 102.7 | 15 | WSAI-FM |
| Cleveland* | 90.3 | 10 | WBOE |
| Cleveland | 103.3 | 14 | WCUO |
| Cleveland | 98.5 | 11 | * WERE-FM |
| Cleveland | 100.7 | 11 | * WHK-FM |
| Cleveland | 104.1 | 19 | WJW-FM |
| Cleveland | 105.7 | 14 | WTAM-FM |
| Clvlnd Hgts | 95.3 | 1 | WSRS-FM |
| Columbus | 92.3 | 33 | WCOL-FM |
| Columbus | 97.1 | 4.1 | WELD |
| Columbus | 98.7 | 15 | WHKC-FM |
| Columbus | 96.3 | 15 | WLWF |
| Columbus* | 89.7 | 14 | WOSU-FM |
| Columbus | 94.7 | 52 | WVKO |
| Dayton | 99.1 | 19 | WHIO-FM |
| Dayton | 97.5 | 18 | WLWB |
| Dayton | 104.7 | 43 | WTWO |
| Elyria | 107.3 | 15 | * WEOL-FM |
| Findlay | 100.5 | 8.2 | WFIN-FM |
| Fostoria | 105.5 | .45 | WFOB |
| Fremont | 99.3 | 1 | WFRO-FM |
| Hamilton | 103.5 | 8.7 | WMOH-FM |
| Kent* | 88.1 | .01* | WKSU-FM |
| Lima | 102.1 | 15 | WIMA-FM |
| Lima | 103.3 | 25 | * WLOK-FM |
| Marion | 106.9 | 2.3 | * WMRN-FM |
| Mt Vernon | 93.7 | 3.2 | * WMVO |
| Newark | 100.3 | 8.5 | WCLT-FM |
| Oxford* | 88.1 | .01 | WMUB |
| Portsmouth | 104.1 | 7 | WPAY-FM |
| Steubenvle | 103.5 | 2 | WSTV-FM |
| Toledo | 101.5 | 20 | * WSPD-FM |
| Toledo* | 91.3 | .73 | WTDS |
| Toledo | 104.7 | 50 | * WTOL-FM |
| Toledo | 99.9 | 8.8 | WTRT |
| Wooster | 104.5 | 13 | WWST-FM |
| Worthington | 97.9 | 340 | * WRFD-FM |
| Youngstwn | 105.1 | 50 | WFMJ-FM |
| Youngstwn | 98.9 | 18 | * WKBN-FM |

**OKLAHOMA**

| | | | |
|---|---|---|---|
| Durant | 107.3 | 2.9 | KSEO-FM |
| Enid | 102.7 | 5.2 | KCRC-FM |
| Muskogee | 98.5 | 3.3 | KBIX-FM |
| Muskogee | 101.5 | 8.7 | KMUS-FM |
| Norman* | 90.9 | 7 | WNAD-FM |
| Oklhma Cy | 94.7 | 176 | * KOCY-FM |
| Oklhma Cy | 105.9 | 3.3 | * KOMA-FM |
| Oklhma Cy | 104.3 | 4 | * KTOK-FM |
| Stillwater | 93.9 | 3.9 | KSPI-FM |
| Tulsa | 95.5 | 9.5 | * KAKC-FM |
| Tulsa | 97.1 | 1.2 | * KTUL-FM |
| Tulsa* | 90.5 | 1.1 | KWGS |

**OREGON**

| | | | |
|---|---|---|---|
| Albany | 101.7 | .71 | KWIL-FM |
| Eugene* | 90.1 | .40 | KRVM |
| Eugene | 99.1 | 8 | * KUGN-FM |
| Grants Pass | 96.9 | 3.1 | KGPO |
| Oretech* | 88.1 | .01* | KTEC |
| Portland | 92.3 | 56 | * KEX-FM |
| Portland | 101.1 | 48 | KOIN-FM |
| Portland | 97.1 | 1.5 | KPFM |
| Portland | 98.7 | 44 | KPOJ-FM |
| Portland | 95.5 | 3.4 | KWJJ-FM |

**PENNSYLVANIA**

| | | | |
|---|---|---|---|
| Allentown | 100.7 | 6.9 | * WFMZ |
| Allentown | 106.3 | .78* | WKAP-FM |
| Allentown | 99.9 | 8 | WSAN-FM |
| Altoona | 103.7 | 3.6 | WFBG-FM |
| Altoona | 100.1 | .13* | WJSW-FM |
| Bethlehem | 95.1 | 10 | WGPA-FM |
| Braddock | 96.9 | 6.9 | * WLFM |
| Butler | 103.9 | .72 | WBUT-FM |
| Butler | 97.7 | .56 | WISR-FM |
| Chambrsbrg | 95.9 | .70 | WCHA-FM |
| Dubois | 102.1 | 9.5 | WCED-FM |
| Easton | 98.3 | 1 | WEEX |
| Easton | 107.9 | 11 | * WEST-FM |
| Erie | 97.1 | 2.5 | * WEEL |
| Erie | 99.9 | 9.7 | * WERC-FM |
| Erie | 97.9 | 7.8 | * WLEU-FM |
| Harrisburg | 100.9 | 1 | WABX |
| Harrisburg | 97.3 | 4 | * WHP-FM |
| Havertown* | 89.3 | .01 | WHHS |
| Hazleton | 97.9 | 7.6 | * WAZL-FM |
| Johnstown | 105.3 | 11 | * WARD-FM |
| Johnstown | 95.5 | 8.3 | WJAC-FM |
| Lancaster | 101.3 | 3.8 | * WGAL-FM |
| Lancaster | 96.9 | 20 | * WLAN-FM |
| Lebanon | 104.1 | 4.7 | * WLAB |
| Lebanon | 100.1 | .72 | WLBR-FM |
| Lewiston | 97.9 | 2.3 | WLTN |
| Meadville | 100.3 | 10 | WMGW-FM |
| McKeesprt | 104.9 | .50 | WMCK-FM |
| New Castle | 101.1 | 3 | WKST-FM |
| Philadlphia | 98.1 | 11 | WCAU-FM |
| Philadlphia | 102.1 | 10 | WFIL-FM |
| Philadlphia | 95.7 | 20 | WFLN |
| Philadlphia | 105.3 | 20 | * WHAT-FM |
| Philadlphia | 94.1 | 17 | * WIBG-FM |
| Philadlphia | 93.3 | 20 | WIP-FM |
| Philadlphia | 102.9 | 20 | WPEN-FM |
| Philadlphia* | 90.1 | .01 | WPWT |
| Pittsburgh | 92.9 | 9 | KDKA-FM |
| Pittsburgh | 98.1 | 20 | KQV-FM |
| Pittsburgh | 96.1 | 12 | WCAE-FM |
| Pittsburgh* | 91.5 | 2.7 | WDUQ |
| Pittsburgh | 99.7 | 24 | WJAS-FM |
| Pittsburgh | 93.7 | 20 | WKJF |
| Pittsburgh | 101.5 | 19 | WPIT-FM |
| Pittsburgh | 94.5 | 20 | WWSW-FM |
| Pottsville | 95.5 | 5.1 | WPAM-FM |
| Pottsville | 101.9 | 2.8 | WPPA-FM |
| Reading | 92.9 | 9 | WEEU-FM |
| Scranton | 93.7 | 2.8 | * WARM-FM |
| Scranton | 101.3 | 1.8 | WGBI-FM |
| Scranton | 92.3 | 1.8 | WQAN-FM |
| Scranton* | 88.1 | .01* | WUSV |
| Sharon | 102.9 | 26 | WPIC-FM |
| Sunbury | 94.1 | 4.4 | WKOK-FM |
| Uniontown | 105.7 | 1.5 | WMBS-FM |
| Warren | 92.1 | .55 | WNAE-FM |
| Washingtn | 104.3 | 6 | WJPA-FM |
| Wilkes-Brre | 98.5 | 2.2 | WBRE-FM |
| Wilkes-Brre | 96.1 | 3.1 | WILK-FM |
| Wilkes-Brre | 103.3 | 3.1 | * WIZZ |
| Williamsprt | 105.1 | 3.2 | WLYC |
| Williamsprt | 100.3 | 3.2 | WRAK-FM |
| York | 105.7 | 13 | * WNOW-FM |
| York | 98.5 | 8 | WRZE |
| York | 103.3 | 20 | WSBA-FM |

**RHODE ISLAND**

| | | | |
|---|---|---|---|
| Providence | 95.5 | 14 | WJAR-FM |
| Providence | 107.7 | 20 | WLIV |
| Providence | 105.1 | 20 | WPJB |
| Providence | 92.3 | 20 | WPRO-FM |
| Providence* | 91.5 | 2.9 | WPTL |
| Woonsockt | 105.5 | .39 | WWON-FM |

**SOUTH CAROLINA**

| | | | |
|---|---|---|---|
| Anderson | 101.1 | 41 | WCAC |
| Charleston | 96.9 | 36 | WCSC-FM |
| Charleston | 95.1 | 49 | WTMA-FM |
| Columbia | 94.5 | 1.3 | * WIS-FM |
| Greenville | 92.5 | 12 | WESC-FM |
| Greenville | 93.7 | 160 | * WFBC-FM |
| Greenville | 94.9 | 79 | WMRC-FM |
| Greenwood | 95.7 | 8.6 | WCRS-FM |
| Rock Hill | 97.5 | 9.4 | WRHI-FM |
| Spartanbrg | 100.5 | 11 | WDXY |
| Spartanbrg | 98.9 | 4.9 | WSPA-FM |

**SOUTH DAKOTA**

| | | | |
|---|---|---|---|
| Rapid City | 94.7 | 16 | KOTA-FM |

**TENNESSEE**

| | | | |
|---|---|---|---|
| Bristol | 96.9 | 10.4 | WOPI-FM |
| Chattanooga | 96.5 | 42 | WDOD-FM |
| Chattanooga | 98.1 | 4.2 | WVUN |
| Jackson | 100.7 | 50 | WTJS-FM |
| Johnson Cy | 100.7 | 9.7 | * WJHL-FM |
| Kingsport | 98.5 | 44 | WKPT-FM |
| Knoxville | 93.3 | 2.8 | WBIR-FM |
| Knoxville | 97.3 | 76 | WROL-FM |
| Knoxville* | 91.9 | 3.4 | WUOT |
| Lenoir City | 100.3 | 8.8 | * WLIL-FM |
| Memphis | 106.9 | 17 | WHHM-FM |
| Memphis | 99.7 | 260 | WMCF |
| Nashville | 97.5 | 71 | WSIX-FM |
| Nashville | 103.3 | 66 | WSM-FM |

**TEXAS**

| | | | |
|---|---|---|---|
| Amarillo | 100.3 | 3.4 | KFDA-FM |
| Beaumont | 99.5 | 14 | * KRIC-FM |
| Belton | 97.1 | 12 | KMHB |
| Cleburne | 94.3 | .33 | KCLE-FM |
| Dallas* | 91.7 | .78 | KVTT |
| Dallas | 104.5 | 34 | KIXL-FM |
| Dallas | 92.5 | 40 | KRLD-FM |
| Dallas | 107.9 | 86 | KYBS |
| Dallas | 101.1 | 68 | WRR-FM |
| Dallas* | 89.3 | .01 | |
| Denton | 106.3 | .76 | KDNT-FM |
| Edinburg | 104.9 | 1 | KURV-FM |
| El Paso* | 88.5 | .01 | KVOF-FM |
| Ft Worth | 100.5 | 50 | WBAP-FM |
| Galveston | 98.7 | 8 | KLUF-FM |
| Goose Creek | 92.1 | .87* | KREL-FM |
| Houston | 102.9 | 57 | KPRC-FM |
| Houston | 101.1 | 29 | * KTRH-FM |
| Houston* | 91.3 | 9.6 | * KUHF |
| Houston | 96.5 | 14 | * KXYZ-FM |
| Longview | 105.9 | 9.8 | KLTI-FM |
| Lufkin | 95.5 | 2.9 | KRBA-FM |
| Plainview* | 88.1 | .01* | KHBL |
| Sn Antonio | 99.5 | 250 | * KISS |
| Sn Antonio | 92.9 | 48 | * KONO-FM |
| Sn Antonio | 101.5 | 15 | * KTSA-FM |
| Temple | 107.5 | 1.9 | KTEM-FM |
| Texarkana | 98.1 | 40 | KCMC-FM |
| Tyler | 101.5 | 4.3 | * KGKB-FM |
| Vernon | 98.7 | 8 | KVWC-FM |
| Wichita Falls | 99.9 | 9.7 | KWFT-FM |

**UTAH**

| | | | |
|---|---|---|---|
| Ephraim* | 88.9 | .01* | KEPH |
| Mt Pleasant* | 88.1 | .01* | KSNA |
| Salt Lke Cy | 98.7 | .90 | KDYL-FM |
| Salt Lke Cy | 100.3 | 5.9 | * KSL-FM |

**VIRGINIA**

| | | | |
|---|---|---|---|
| Arlington | 105.1 | 2.9 | * WARL-FM |
| Crewe | 104.7 | 14 | WSVS-FM |
| Danville | 97.9 | 32 | WBTM-FM |
| Harrisnbrg | 100.7 | 36 | * WSVA-FM |
| Lynchburg | 97.5 | 3.7 | WLVA-FM |
| Lynchburg | 100.1 | .94 | WWOD-FM |
| Martinsville | 96.3 | 2.7 | WMVA-FM |
| Newprt Nws | 96.5 | 38 | WGH-FM |
| Norfolk | 102.5 | 8.2 | * WRVC |
| Norfolk | 97.3 | 50 | WTAR-FM |
| Portsmouth | 99.7 | 100 | WSAP-FM |
| Richmond | 98.1 | 34 | WCOD |
| Richmond | 102.9 | 21 | * WLEE-FM |
| Richmond | 102.1 | 50 | WRNL-FM |
| Richmond | 94.5 | 25 | WRVB |
| Roanoke | 94.9 | 41 | WDBJ-FM |
| Roanoke | 103.7 | .28* | WROV-FM |
| Roanoke | 99.1 | 4.7 | WSLS-FM |
| Suffolk | 107.7 | 10 | * WLPM-FM |
| Winchester | 92.5 | 13 | WRFL |

**WASHINGTON**

| | | | |
|---|---|---|---|
| Longview | 103.9 | .41 | KWLK-FM |
| Pasco | 103.9 | .58 | KALE-FM |
| Seattle | 98.1 | 15 | KING-FM |
| Seattle | 100.7 | 4.5 | * KIRO-FM |
| Seattle | 99.9 | 2.1 | KISW |
| Seattle | 98.9 | 14 | KOMO-FM |
| Tacoma | 97.3 | 10 | KTNT |
| Tacoma* | 91.7 | 3.5 | KTOY |

**WEST VIRGINIA**

| | | | |
|---|---|---|---|
| Beckley | 101.3 | 35 | WCFC |
| Beckley | 99.5 | 34 | WJLS-FM |
| Charleston | 98.5 | 5.2 | WGKV-FM |
| Charleston | 97.5 | 22 | * WKNA-FM |
| Clarksburg | 95.1 | 2 | WPDX-FM |
| Fairmont | 92.3 | 4.8 | WJPB |
| Huntington | 100.5 | 53 | WHTN-FM |
| Huntington | 102.5 | 41 | WPLH-FM |
| Logan | 103.3 | 2.7 | WLOG-FM |
| Martinsburg | 94.3 | .81* | WEPM-FM |
| Morgantown | 99.3 | 1 | WAJR FM |
| Oak Hill | 94.1 | 19 | WOAY-FM |
| Parkersbrg | 106.5 | 8.9 | * WPAR-FM |
| Wheeling | 97.3 | 16 | WKWK-FM |
| Wheeling | 98.7 | 15 | * WWVA-FM |

**WISCONSIN**

| | | | |
|---|---|---|---|
| Chilton* | 89.3 | 51 | WHKW |
| Colfax* | 88.3 | 50 | WHWC |
| Delafield* | 90.7 | 52 | WHAD |
| Eau Claire | 94.1 | 60 | WEAU-FM |
| Greenbay | 101.1 | 14 | WJPG-FM |
| Greenfield | 94.9 | 37 | WWCF |
| Holmen* | 90.3 | 25 | * WHLA |
| Janesville | 99.9 | 15.5 | WCLO-FM |
| Madison | 104.9 | .93 | WFOW |
| Madison | 101.5 | 207 | * WIBA-FM |
| Madison | 98.1 | 52 | * WISC-FM |
| Madison* | 88.7 | 9.3 | WHA-FM |
| Marshfield | 103.9 | .25 | WDLB-FM |
| Merrill | 100.7 | 20 | WLIN-FM |
| Milwaukee | 94.1 | 35 | WEMP-FM |
| Milwaukee | 102.9 | 55 | * WISN-FM |
| Neenah | 98.5 | 3.2 | WNAM-FM |
| Oshkosh | 92.9 | 3.5 | WOSH-FM |
| Racine | 100.7 | 15 | WRJN-FM |
| Rice Lake | 96.3 | 4.4 | WJMC-FM |
| Sheboygan | 100.3 | 15 | WHBL-FM |
| Waukesha | 95.3 | .23* | WAUX-FM |
| Wausau* | 91.9 | 114 | WHRM |
| Wis Rapids | 103.3 | 2.1 | WFHR-FM |

*Precision, High-Temperature Adhesive Tape*

# RESISTORS FOR PRINTED CIRCUITS

## NEW DEVELOPMENT IN PRINTED-CIRCUIT TECHNIQUES PRODUCES ACCURATE, INEXPENSIVE RESISTORS WITH GOOD STABILITY AT HIGH TEMPERATURES*

PRINTED electronic circuits, in which components and wiring are superimposed directly on insulating bases, are being used increasingly because of their adaptability to mass production, and because they facilitate miniaturization of equipment. A major disadvantage of the printed-circuit method, however, has been the difficulty of incorporating satisfactory resistors in the circuits. This difficulty has been overcome by an adhesive tape resistor recently devised by B. L. Davis and associates at the National Bureau of Standards.

In this technique, circuits are first printed in narrow metallic bands on insulating bases, leaving a small gap at each point where a resistance is required. One of the self-adhesive resistors is then cut from a strip and pressed into position, as in Figs. 1 and 2. Much better control of resistance values is possible than with previous printed resistor methods, and higher yields of acceptable assemblies are obtained. Thus, the new method combines the advantages of printed resistors and of separately-manufactured resistors. The NBS tape resistor was developed to withstand the high temperatures of very compact equipment, and operates satisfactorily at temperatures up to 200°C; in other electrical characteristics it is similar to present film-type carbon resistors.

*From a technical report by the National Bureau of Standards, Washington 25, D. C.

The usual method of introducing resistances into printed circuits has been to paint or spray a strip of resistance material directly on the base plate. The desired value of resistance is obtained by varying the composition and dimensions of the resistance strip laid down. Production of individual resistors to close tolerances by this direct-coating method is difficult, and reduces the probability of producing a number of satisfactory resistors on the same base plate, thus greatly decreasing the yield of acceptable assemblies.

**Manufacturing Techniques:** Compositions and techniques used in making and applying the new tape resistors are remarkably simple. The resistors consist of a mixture of graphite or carbon black, resin, and solvent applied in a thin layer to a roll of asbestos paper tape.[1] The resistive coating is sufficiently adhesive to stick to an insulating base plate and to make satisfactory electrical contact with metallic terminals. When the resistor is in position, the resistance film is protected from abrasion and electrical shorts by its asbestos-tape backing. A variety of coating formulations provides a range of values from about 100 ohms to 10 megohms, as shown in Table 1.

The resistors are manufactured by spraying the resistance mixture onto a moving belt of tape, Fig. 3. A protective film of polyethylene, about .002 in. thick, is pressed lightly over the resistance coating for protection in handling and storage. It is easily removed when the resistor is used. An electrically-driven slitting machine, shown in Fig. 4, cuts the tape quickly into long strips of the desired width.

[1] "Quinterra" tape (Johns Manville, New York) has been found satisfactory.

At present, the resistor tape, cut to width, is applied to printed circuitry by hand from a continuous spool. The tape is pressed into position and cut off with a razor blade. Figs. 1 and 2 show the application of the resistors to printed circuits. In mass-produced flat circuit assemblies, gaps are left in printing for the insertion of resistors. The appropriate resistor strips are pressed into place and the complete assembly cured. Plans call for development of a device comparable to a wire stapler, which will accept a roll of the resistor tape and apply and cut off a resistor of standard length each time a knob or handle is pressed.

Silicone resin[2] is used for the binder-adhesive because of its suitability for high-temperature operation. Since the curing temperature of silicone resin formulations is about 300°C., and since curing is done after the resistors have been positioned in the circuit, the NBS

[2] DC 996 is the preferred resin of those investigated so far.

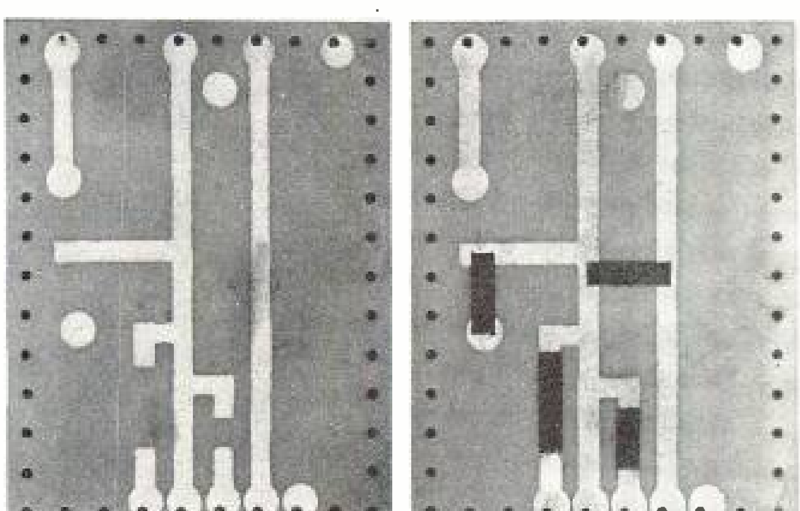


FIG. 1. METHOD OF APPLICATION ON FLAT PRINTED-CIRCUIT BASE

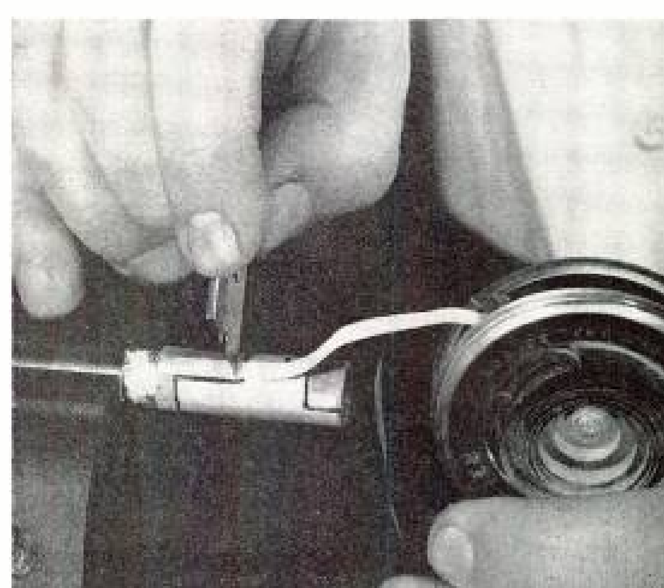


FIG. 2. TAPE IS CUT OFF A ROLL IN DESIRED LENGTHS AS IT IS USED

tape resistor is at present applicable only to glass or ceramic-base materials. However, enough work has been done with other resins to indicate definitely that they can be used in making tape resistors with cure temperatures low enough for application to some heat-resisting plastic materials. These resistors would be suitable for conventional operating temperatures.

### Fixing Resistance Values:

The possibility of varying resistor dimensions to obtain a range of values was considered but rejected. The so-called "aspect ratio" system has the advantage of reducing the number of formulations needed for a complete resistor range, but it complicates equipment design and production. Resistor dimensions were therefore standardized at a length of 0.5 in. (0.3 in. interelectrode distance) and a width of 0.13 in. ±0.02 in. This slight leeway in width permits some adjustment of resistor values in the slitting operation. With constant dimensions, wattage ratings are substantially independent of resistance value, and different contact resistance values due to different contact areas of silver and resistor are eliminated.

Both natural and synthetic graphites, as well as various carbon blacks, are used in the resistor formulations, as indicated in Table 1. Values of resistors are varied by changing the ratio of carbon to resin in the mixture, and by using various carbons. This is shown in Fig. 5. The proportion of carbon to resin ranges from 10 to 50%, with leaner mixtures giving less favorable results.

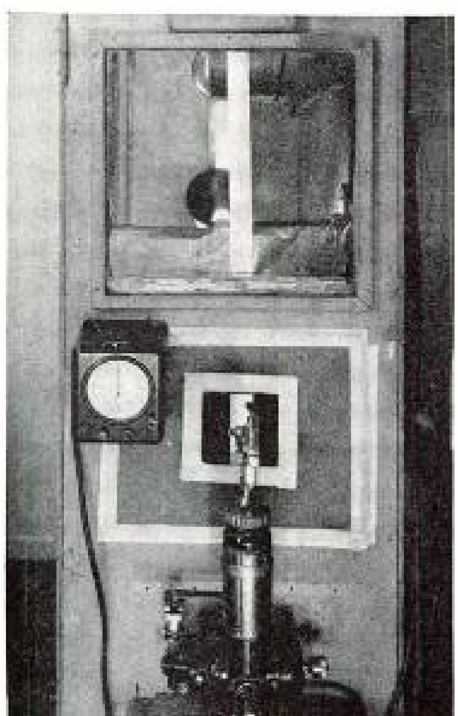


FIG. 3. SPRAY BOOTH FOR APPLYING COATING

Tape resistors made from graphite mixtures have proved remarkably stable at ambient temperatures of 200°C. Another advantage of graphite formulations is that unusually low resistance values — down to about 100 ohms — can be obtained. Unfortunately, however, the useful upper limit of the graphite formulations seems to be about 5,000 ohms. Carbon blacks, which are less desirable at high temperatures, give values from 5,000 ohms to 10 megohms. Only a few carbon blacks have been found satisfactory for this type of use at 200°C. For most resistance ranges, however, carbon-black tapes have been made which are satisfactory at 170°C.

TABLE 1

| RESISTOR VALUE | FORMULATIONS |
|---|---|
| 200 ohms | 2.5 Dixon Graphite 200-09<br>1 Dag 22 |
| 500 | 4 Dixon Graphite 200-09 |
| 1K | 5 Dixon Graphite 200-09<br>2 Dag 22<br>4 Dixon Graphite 200-10 |
| 2K | 6 Dixon Graphite 200-09<br>4.5 Dixon Graphite 200-10 |
| 5K | 4 Statex<br>3 Dag 22<br>8 Halo |
| 10K | 5 Statex<br>7 Sterling 105<br>10 Halo |
| 20K | 6 Statex<br>8 Sterling 105<br>12 Halo |
| 50K | 7.5 Statex<br>10 Sterling 105<br>8 Sterling 99 |
| 100K | 8.5 Statex<br>6 Continental AA |
| 200K | 9.5 Statex |
| 500K | 7.5 Continental AA |
| 1 MEG | 8 Continental AA |
| 2 MEG | 9 Continental AA |

Formulations are listed in order of preference. Number before each commercial carbon designation indicates the ratio of DC 996 silicone resin solids to the carbon named. Solvent is added to make the ratio of solvent to total solids 2 to 1.

The coating formulation, consisting of carbon, resin, and solvent, is agitated with porcelain balls in a ball mill for at least 72 hours before it is sprayed on the tape. Spraying is done in a special cabinet, Fig. 3. To secure a uniform coating, the tape, in the form of an endless belt 13 ft. long and 1¼ ins. wide, is moved rapidly past a spray gun many times, as the spray mixture is deposited slowly. Infrared heat lamps, mounted within a few inches of the moving tape, hasten removal of solvent during spraying, and dry the tape to the desired degree of stickiness after spraying is stopped.

The tape-slitting machine, Fig. 4, employs 12 disk knives mounted in pairs, slightly overlapping so as to give a scissors action, and separated by accurately-ground spacers. A small sample of the tape can be tested for value before the entire tape is slit. Testing is done by

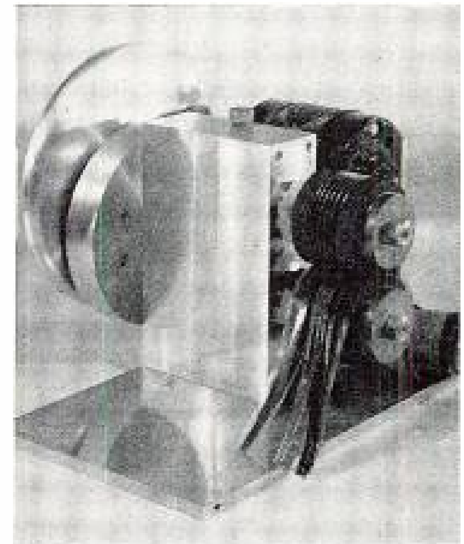


FIG. 4. PRECISION TAPE-SLITTING MACHINE

cutting the sample into a series of strips varying in width by 0.01 in. over the range from 0.11 to 0.15 in., and making up a test plate from these strips. On the basis of test results, the slitter is set to cut the entire roll into strips of the width necessary to give the desired final resistance value. A single belt of resistance tape yields approximately 1,500 resistors.

Proper curing of the resistors after application to the printed circuitry is extremely important. The curing process hardens the resistor, bonds it more firmly to the plate, and stabilizes its electrical characteristics. Although the optimum cures for different formulations differ considerably, a compromise cure of 4 hours at 300°C. has proved satisfactory, and has been adopted as standard. Curing is done in a temperature-controlled electric furnace, to which an aluminum inner liner has been added for more uniform temperature distribution.

In using the resistors at 200°C., it has been found that those made from some formulations change sharply in value during the first 24 hours, then remain stable for several hundred hours. For this reason, there is some advantage in following the standard 4-hour cure at 300°C. with a 24-hour treatment at 200°C. As changes in the resin in the resistor film take place quite slowly at room temperature, the resistor tape can be stored for long periods. Its storage life can be further extended by refrigeration.

Testing and development of tape resistors are continuing at the Bureau. This work utilizes a test oven of a design which permits automatically-recorded measurements to be made simultaneously on a large number of resistors without their removal from the oven. Improved resistance formulations are being sought, particularly for certain

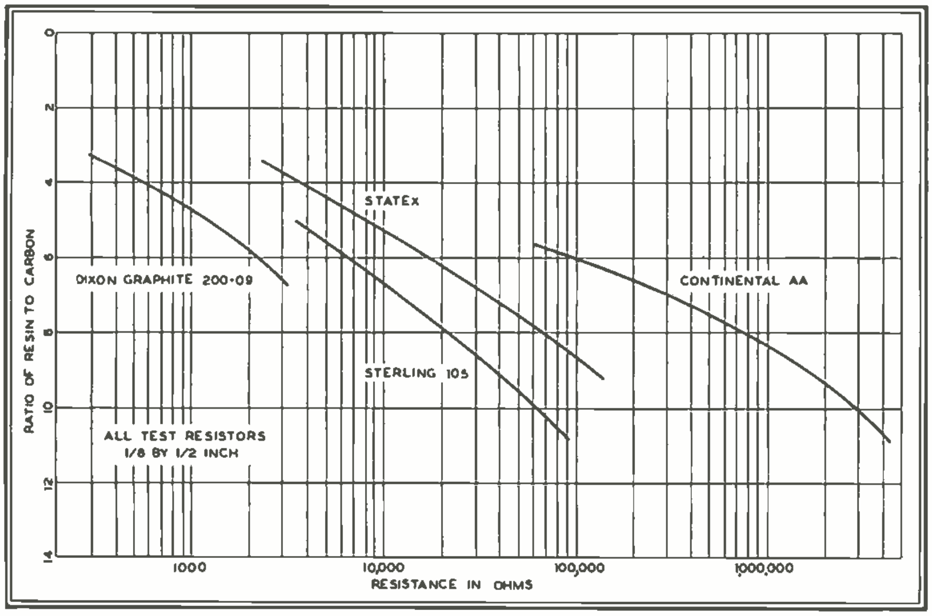



FIG. 5. RESISTANCE VALUES OBTAINABLE WITH VARIOUS CONCENTRATIONS OF CARBONS SHOWN

ranges. Attempts are also being made to develop a satisfactory additional protective coating for application to resistors after they have been mounted.

# DUPLICATE OPERATORS

## CANADA'S DEPT. OF TRANSPORT PERMITS OPERATION OF UNATTENDED BROADCAST TRANSMITTERS

When plans are being made for the construction of a broadcast station, it is rare indeed that the most desirable locations for the transmitter and for the studios coincide. Usually, the best site for the transmitter and antenna is well outside the urban area which is, for reasons of convenience, the most practical place for the studios.

### The Location Dilemna:

Only in exceptional cases does the FCC permit unattended operation of broadcast transmitters. In such cases extremely elaborate monitoring facilities and safety devices are required. But these facilities are usually out of financial reach of small stations, which need them most in order to avoid duplication of operating personnel. This situation creates a dilemma which is usually solved by placing the transmitter and studios at the same location, which may be the best spot for one but not for the other—hardly a satisfactory solution.

### Canadian Policy:

On the other hand, the policy of the Telecommunications Branch of the Department of Transport (Canadian equivalent of the FCC) is more favorable toward unattended operation, recognizing that many smaller stations in Canada would be forced to close down their transmitters if duplication of operating personnel were mandatory. Reasonable monitoring facilities are required, but they are minimum consistent with high operating standards.

### Operating Rules:

The Department of Transport's directive concerning unattended transmitters has been in effect for some time. No difficulties have yet been experienced by stations operating under these conditions. Broadcast Specification No. 8, covering Unattended Operation of Broadcast Transmitters, is given below as a model of practical rule-making:

"Unattended operation of broadcast transmitters up to and including 5-kw. power will be permitted provisionally provided that the following requirements are fully and satisfactorily met:

1. The transmitting equipment, including transmitter, antenna system, auxiliary equipment, and accommodation, shall be approved by the Radio Division as complying with the requirements governing such matters.

A. Provision shall be made for the telemetering of all major circuits in the transmitter, antenna system, and auxiliary equipment with the indicating instrument accessible to personnel who will be on duty and responsible during the entire period of the transmitter operation, or

B. A graphical recording meter shall be arranged at the transmitter to record cyclically and at intervals not longer than 1 hour apart, all major circuits in the transmitter, antenna, and auxiliary equipment, with provision made for identifying on the graphical record so produced which circuits have been measured, or

C. An alarm system may be employed using marginal relays in all major circuits, with a locked-in signal system and signalling devices accessible to personnel who will be on duty and responsible during the entire period of the transmitter operation.

2. If a telemetering system is used, a log shall be kept of all readings metered, with entries at regular intervals; or if a graphical recording method is used, charts shall be labelled as to date, period covered, and sufficient information regarding calibration so that subsequent analysis of the chart may be made to determine how the transmitter performed over the period for which it was charted. If the alarm system is used, a log shall be kept of all instances of alarm operation and the reason therefor, and at least daily entries must be made regardless of alarm operation.

3. A satisfactory schedule of maintenance must be declared and carried on throughout the period during which the transmitter is operated unattended. Such schedule must provide for a general inspection of the transmitting equipment at least once a week, and a general overall test at least once a month. The extent of the inspection and test must be satisfactory to the Radio Division.

4. If a transmitter is authorized to be operated unattended, the frequency and modulation monitors must be installed either at the studio under constant supervision, or provision must be made for the indication at the studio of their readings, if this equipment is installed at the transmitter site."

The procedure for obtaining authority for the remote operation of transmitters is as follows:

"A letter must be obtained from the Department of Transport, Ottawa, before equipment is installed for the unattended operation of a broadcast transmitter. The following is the proper procedure, as set forth by the Department, for applying to this authority:

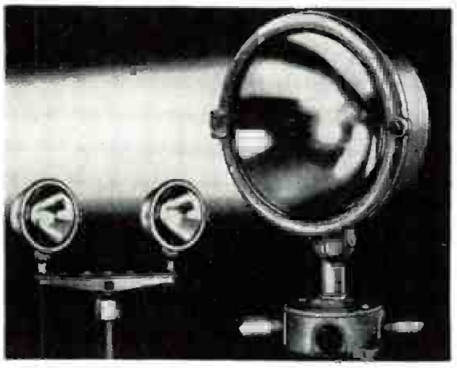
"A letter must be prepared and signed by the licensee of the station or his agent making formal application for unattended operation. The letter must be accompanied, or followed closely, by two copies of a technical brief prepared by a recognized consultant, showing the exact manner of operating the transmitter unattended. This technical brief must show

*(Continued on page 36)*

# NEW EQUIPMENT AND COMPONENTS

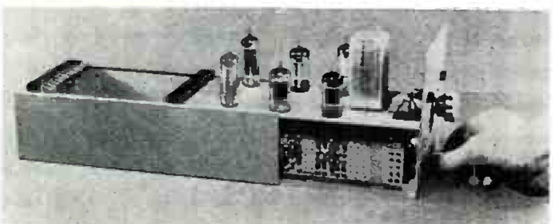
**LEFT:** Portable PA system has two 12-in. speakers, mounted in a split case. Two models offer a choice of 17 or 25-watt amplifiers, with frequency response rated at 20 to 20,000 cycles. The low-power type has input connections for 2 microphones and a phonograph, while the high-power type has 3 microphone inputs plus the phonograph. There are individual bass and treble tone controls. Either model can be provided with remote controls for all microphones, operating at distances up to 2,000 ft. Case is covered with Fabricoid material, and furnished with kick-proof speaker grilles. The amplifier unit can be detached quickly from the carrying case If servicing is required. Overall size is 11 by 20½ by 21 ins. Newcomb Audio Products Company, 6824 Lexington Ave., Hollywood 38, Calif.

**ABOVE:** Low-power, 2-way mobile unit, with Motorola sensicon receiver, for industrial installations. Can be mounted on fork-lift trucks and other material-handling equipment. Output is 3 watts to final amplifier. For 6 or 12 volts DC, 117 volts AC. Motorola Inc., Chicago 51.



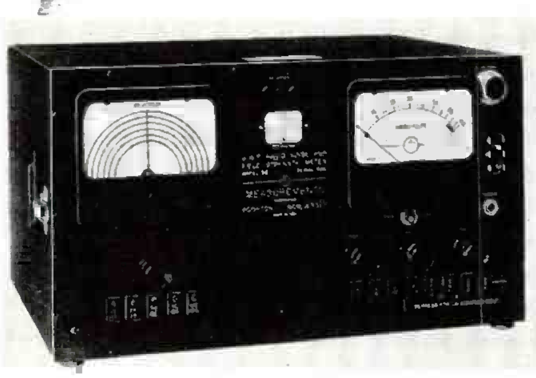
**LEFT:** An outdoor spotlight providing 100,000 candlepower from a 300-watt bulb. Reflector is designed to concentrate light in an oval beam, suitable for the protection of broadcast stations, and buildings which require continuous or emergency night lighting. All parts are of aluminum. Up to 5 units can be mounted together, using standard accessories. Swivel arm is threaded ½-in. NPT for conduit fittings. These units are fully approved by the Underwriters Laboratories. Stonco Electric Products Co., 489 Henry Street, Elizabeth, New Jersey.

**RIGHT:** Klystron power supply designed for test-bench operation of all types of low-power klystron oscillators. Furnishes beam voltage continuously variable from 250 to 400 volts at 50 milliamperes maximum; reflector voltage from 10 to 900 volts at 5 microamperes; filment supply of 6.3 volts at 1.5 amperes. In addition, this instrument provides for square-wave modulation at 1,000 cycles, or moduation can be applied from an external source. Steel case has carrying handle. Model No. 715A. Hewlett-Packard Company, 395 Page Mill Road, Palo Alto, Calif.

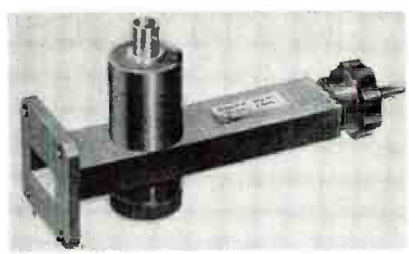


**LEFT:** Plug-in, standard chassis is designed for adaptability to all kinds of circuit assemblies. A connector block at the rear provides external connections to the removable chassis. As the illustration shows, there are pierced terminal boards on each side of the chassis for inserting terminals on which components can be mounted. These assemblies are intended both for experimental and development work, as well as for standard production purposes, singly or in combinations. Alden Products Company, Brockton 64, Mass.

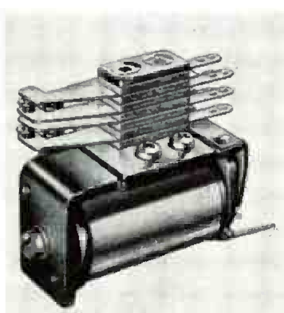
**BELOW:** A detector mount designed to facilitate measurements of power at any frequency between 2,600 and 18,000 mc. in conjunction with the Hewlett-Packard type 430A power meter and a Sperry type 821 barretter. It can be used also to measure relative level or to detect RF energy, using a 1N21 silicon crystal. The mount is semi-tuned by means of a movable short. Tuning can be provided by adding a tuning element. Sizes are available from 2 by 1 in. to .702 by .391 in. Hewlett-Packard Co., Palo Alto, Calif.

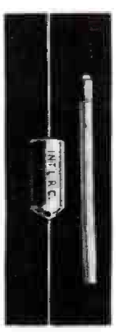


**LEFT:** Radio noise and field-strength meter incorporates the slide-back technique in the vaccum-tube voltmeter circuit. Purpose is to make possible more accurate noise measurements of short pulses having a slow repetition rate, or a random variation over a considerable period of time. This new feature can be addec to model 58 meters already in use, by means of a kit supplied for that purpose. Measurements Corporation, Boonton, N. J.



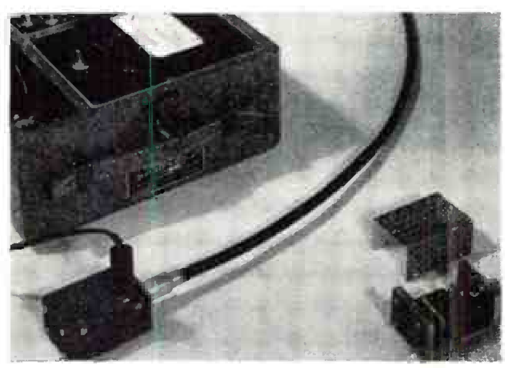
**BELOW, RIGHT:** Small, resistive-load RF wattmeters for use with Motorola P-8501 or P-8501-A test sets, or any 0-50 micro-ammeter. Two types are available, one for measurements of RF power output of 0-60 watts, and one for 0-2 watts. Motorola, Inc., Chicago 51.

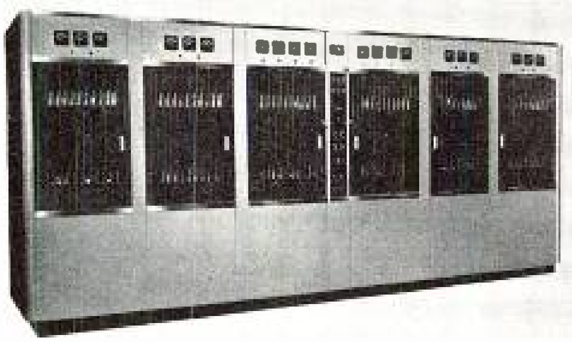




**FAR LEFT:** Type KX is a refinement of the Clare type X small-size relay. Increased sensitivity and operating range have been achieved in the new model by a change in the armature suspension, permitting the use of a longer coil. Maximum resistance is now 8,000 ohms. C. P. Clare & Co., 4719 W. Sunnyside Ave., Chicago 30.

**LEFT:** Hermetically sealed selenium rectifier for assembly in a half-wave cartridge. Made in current ratings from 300 microamperes to 60 milliamperes. A single cartridge with 400 cells can handle DC voltages up to 8,000 volts. Operable at ambient temperatures up to 100° C. International Rectifier Corp., Los Angeles 43.





**LEFT:** VHF television transmitter with a nominal peak visual power output of 10 kw., and 5 kw. aural power output. High-gain, air-cooled tetrodes are employed in the final amplifiers of both visual and aural sections. Grid modulation permits individual, non-critical meter tuning of all RF circuits. All driver stages operate as high-efficiency, narrow-band class C amplifiers. Designed for use on lower or upper VHF band. Dimensions 192 by 84 by 32½ ins. RCA Victor, Camden, New Jersey.

**RIGHT:** New version of the FM Handie-Talkie incorporates an adjustable squelch. Purpose is to reduce the annoyance of tube and circuit noises normally heard in the absence of radio signals. Squelch control, mounted on the power supply chassis, provides a range from no-squelch up to 25 to 50 db noise reductions. This model is available with either wet or dry cells for the power supply, and for operation on 25 to 50 or 152 to 174 mc. Motorola, Inc., 4545 Augusta Blvd., Chicago 51.

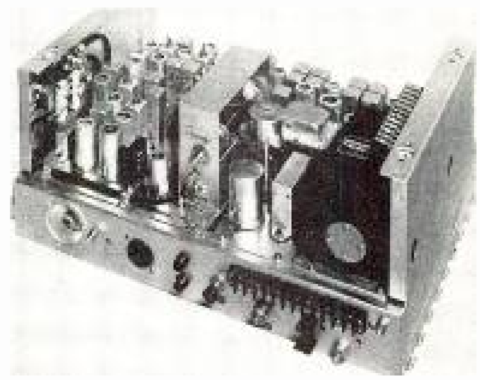
**LEFT:** Attenuator for microwave circuits, operating on the principle of a waveguide beyond cut-off. The calibration curve of the dial is a straight line from 10 to 155 db, at 0 to 120 scale divisions. This device has an impedance of 50 ohms. Designed to cover 4,000 to 12,000 mc. Polarad Electronics Corp., 100 Metropolitan Avenue, Brooklyn 11.

**RIGHT:** Time-delay generator for producing delay intervals of 10 microseconds to 10 seconds. There are 5 ranges, giving full-scale of .001 second to 10 seconds. Blocking oscillator and single-shot output wave forms are provided. Front panel is intended for 19-in. rack mounting. Rutherford Electronics Co., Culver City, Calif.

**BELOW:** Combination transcription player and PA unit has a 5-tube push-pull amplifier of about 5 watts output into an 8-in. speaker. Turntable takes up to 17½-in. discs, and operates on 3 speeds. Dual-twist crystal cartridges are supplied. Case is of Fabricoid. Weight is 15 lbs. Audio-Master Corp., 341 Madison Ave., N. Y.

**BELOW:** Five-inch oscilloscope designed for use with microwave installations. All operating potentials have electronic voltage regulation, to permit use under extreme line voltage fluctuations. Vertical sensitivity AC input is .075 volt rms. per inch, with frequency response 20 cycles to 3 mc. General Electric, Syracuse, N. Y.

**RIGHT:** Mobile radio transmitter-receiver unit designed specifically for use for forestry departments and installations in remote sections where special emergency systems are authorized. Also suited to conventional mobile radio services. Special emphasis has been put on design features which reduce the necessity of repairs and replacements under field service conditions. Radio Specialty Mfg. Co., E. 6th Avenue, Portland, Ore.

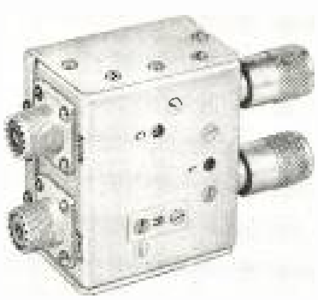


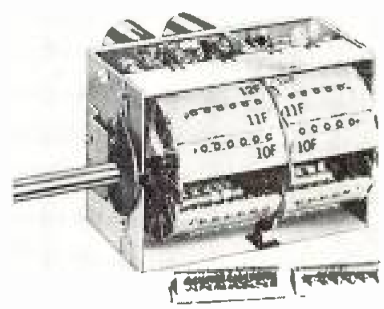
**RIGHT:** A periodic power amplifier of wide frequency range, covering 20 cycles to 20 kc., 20 kc. to 1.5 mc., and 20 kc. to 3 mc. Output is 15 watts maximum. In addition to its use as an all-purpose laboratory or testing amplifier, it can be employed to excite broadcast antennas for measurements with deflection-type instruments, and as an oscilloscope deflection amplifier. With a tuned input, it can drive a modulation monitor. Type 1931-A. General Radio Co., Cambridge, Mass.

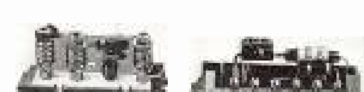
**BELOW:** Moderately-priced 1,000-ohms-per-volt multimeter has 31 ranges, including 0-1 volt on both AC and DC. The 3½-in. meter has a 400-microampere movement. Resistors are rated at 1% accuracy. DC accuracy rated minus 3% full scale; AC, plus or minus 5%. Electronic Instrument Co., 276 Newport Street, Brooklyn 12.

**BELOW, LEFT:** Video line pad is provided with connectors for 1 or 2 line amplifier outputs, a line input, and a monitor input. The network feeds from a 73-ohm source to a 73-ohm line with zero loss, with a branch circuit of 14 db isolation for a high-impedance monitor. The Daven Company, 191 Central Avenue, Newark 4, N. J.

**BELOW:** This TV tuning turret, of the type used by a very large number of television set manufacturers, is shown with the standard coil assemblies for VHF channels, and a set of coils for UHF reception. Thus the turret is intended to handle any combination of the VHF and UHF channels. Standard Coil Products Co., Inc., Chicago 39.



**ABOVE, RIGHT:** Branching network for equalizing incoming signal levels in multi-channel mixers and similar broadcast equipment. Can be used to combine 2 or more incoming lines into 1 outgoing line, or to divide an incoming line. The Daven Company, Newark, N. J.

JEREMIAH COURTNEY'S

# MOBILE RADIO

NEWS AND FORECASTS

RELAY stations may now be used in the industrial and railroad mobile radio services to extend the range of communication between mobile units. Amendments to industrial and land transportation Rules permitting such use became finally effective September 24.

Principal provisions of the new Rules are set forth in the following text.

### Mobile Relay Licenses:

Mobile relay licenses will only issue upon convincing showing of operational need for extended car-to-car communications range. An REA cooperative, supplying power over a large and lightly populated area, with continuing need for communications between scattered work crews located anywhere in the area, is a good example of the kind of operational need that will qualify an applicant for mobile relay use.

In the example cited, REA Work Car No. 1 would transmit on mobile frequency A. The relay station, located on a mountain top or other elevation, would pick up Car No. 1 message on frequency A and automatically retransmit the message on Frequency B to all other REA mobile units. REA main office receiver would also pick up the retransmission of the message from Car No. 1, as well as from other mobile units, assuring centralized control over all mobile units of system. Note use of two frequencies to handle a single message. This is why applicants must demonstrate convincing need for extended car-to-car communication range before they will get mobile relay licenses.

### Control Stations:

Headquarters control stations of such systems must use the 72 to 76-mc. band or, if TV is operating on channels 4 or 5 in the area, the 450 to 460-mc. band. (Amendment to railroad Rules is expected to permit secondary use of 450 to 460 mc. for fixed communications as now permitted under industrial Rules.) In the REA example cited, the main office transmitter actuating the mountain-top mobile relay station must operate on 72 to 76 or 450 to 460 mc. Main office transmissions would be picked up on second receiver at mountain-top location, and automatically retransmitted on frequency B to all mobile units of system. REA system described would thus be a 3-frequency system consisting of one operational fixed and two mobile frequencies.

### Frequency Availability:

Only mobile frequencies above 47 mc. will be authorized to transmit to relay stations. Line of demarcation is drawn at 47 mc. because of the long-distance (F-2 layer) propagation of the lower frequencies. Purpose is to eliminate unnecessary transmissions from the relay station, resulting from random triggering by reception of distant mobile units.

The limit of 47 mc. does not apply to operating frequencies of relay stations, however. A frequency below 47 mc. may be used, provided such a frequency has been allocated to the service in question. But no more than two mobile frequencies to a customer.

### Coded Signal Device:

When mobile units of a relay system operate on 47 to 50 mc., the mobile relay station must be equipped with a signal device coded to the associated mobile units, in order to prevent triggering of the mobile relay station by non-system units operating on the same frequency. No exceptions.

When the mobile units of a relay system operate in the 152 to 162-mc. band, or higher, requirement of coded-signal device will be waived upon showing that no one else is using applicant's mobile frequency within 75 miles of proposed relay station or, if another system is using same frequency, it has given written consent to applicant's use. FCC reserves right to cancel waiver of coded-signal device requirement upon 90 days' notice if complaints of consistent interference are received from other users in area.

### Open Questions:

Rule amendments leave two questions open: 1) whether mobile frequencies should be used for operational fixed (control) stations; and 2) whether mobile relay stations should be used for extended-range point-to-mobile communications not now allowed. On these two points, FCC said in effect that they didn't know, and would hold a hearing to find out what should be done. Commission Report and Order on whole subject demonstrated careful study of all questions raised. Report, furthermore, evidenced nice balance of informed firmness and open-mindedness, doing great credit to staff draftsmen who studied the record and prepared the Report on this subject for Commission action.

### Bell Laboratories' Petition:

The Bell system, through its research and developmental organization, Bell Telephone Laboratories, Inc., has filed a petition asking the FCC to allocate additional space in the 216 to 470-mc. band for common carrier mobile telephone purposes. Petition filing followed on heels of FCC assignment of 470 to 500 mc. for TV use.

Bell Labs asked for a 30-mc. band in seven most heavily-populated areas in the country, namely, Boston, New York-Newark, Philadelphia, Detroit, Chicago, San Francisco and Los Angeles; a 20-mc. band in 22 medium-populated areas; and a 15-mc. band in remaining areas of the Country. Large space segment request was based on broad-band method of operation which, petition stated, has "great possibilities in providing large number of channels for mobile telephone communication in congested areas, with maximum efficiency and economy in the use of frequency space." Although petition was phrased in terms of allocation for "mobile telephone service," presumably miscellaneous common carriers would share in use of any allocations made in view of announced Commission policy to foster competing techniques and services in the common carrier mobile field. Since grant of petition would involve taking of space previously assigned to other services, prospects of any early action on petition appear unlikely. Probably for this reason, petition also requested engineering conference with FCC staff to consider plans for geographical sharing of frequencies not used by other services in congested metropolitan areas.

### Civil Defense Interpretation:

Use of radio systems in Civil Defense tests authorized by competent local authority has been interpreted by FCC as falling into category of safety communications. This means that all mobile radio licensees (except common carriers who cannot provide such services without payment of tariff charges) may use their radio systems for Civil Defense tests without getting prior FCC authorization as formerly required. Point-to-point uses are authorized for safety

*(Concluded on page 37)*

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# EQUIPMENT PERFORMANCE SPECS

## A NEW METHOD FOR PREDICTING THE ADJACENT-CHANNEL PERFORMANCE OF MOBILE RADIO EQUIPMENTS BY GRAPHICAL ANALYSIS — *By* T. S. EADER*

DURING the past few years, with rapid increase in radio communications systems especially in the 152 to 174-mc. band, there has been more and more emphasis on adjacent-channel operation. As a result, receiver IF systems have been made more and more selective, approaching virtually vertical slope as a goal. A specification often quoted as necessary for adequate adjacent-channel operation is that the selectivity should be 100 db at ±30 kc. That is, with signals of a maximum deviation of 15 kc., and channels 60 kc. apart, the attenuation at 30 kc. off resonance should be 100 db to give satisfactory rejection of signals 60 kc. off.

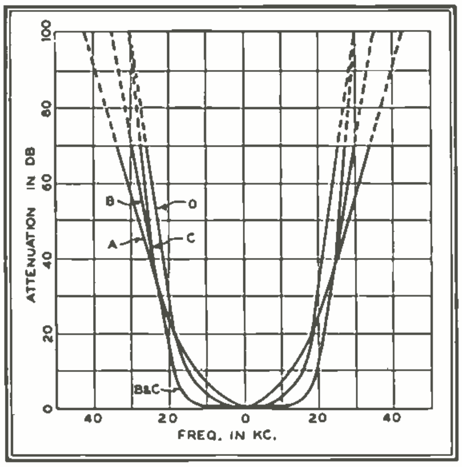


FIG. 1. SELECTIVITY OF 4 TYPICAL RECEIVERS

**Selectivity Measurement Methods:** How is this attenuation or selectivity measured? There has been two accepted methods. One is that of measuring the overall IF gain versus frequency off resonance for a constant output, usually a fixed value of 2nd limiter current.

The other method is the 20-db quieting measurement. This has the advantage of using a signal fed through the front end of the set and is, therefore, an overall measurement. A convenient means of determining the relative sensitivity of an FM receiver is to measure the on-frequency unmodulated signal that will give 20 db reduction of noise output of the receiver. This method has been extended to get a measure of selectivity by shifting the signal off frequency, and measuring the increase of signal necessary to maintain 20 db quieting.

The selectivity curve, when expressed in db with reference to the on-frequency 20-db quieting sensitivity, agrees very closely to the overall IF selectivity and, therefore, it was taken as a measure of overall receiver selectivity.

Fig. 1 shows the selectivity of four receivers as measured by the 20-db quieting method. It will be seen that the upper portions of the curves are shown in dashed lines. The last point that can be actually measured falls between 60 db and 80 db, depending on the receiver in question. This occurs because desensitization of the receiver has started. The signal reaches a level such that some grid prior to the limiters starts to draw grid current and biases itself. Reduction of gain with resultant reduction of quieting begins. When this point is reached, no matter how much the signal is increased, 20-db quieting cannot be produced. Beyond that point, the curves are extrapolated by projecting them as indicated by the dashed lines. No one knows exactly what form the curves should take above this point, or what the bandwidth is at 100-db attenuation. The same limitation also occurs with an overall IF selectivity curve.

Field tests of these receivers showed that in adjacent-channel operation equipment represented by curve A, Fig. 1, was equal to or slightly better than other types of receivers which had considerably greater IF selectivity, such as curve B or curve C. However, when it is realized that the 20-db quieting selectivity measurement is a single-signal measurement, and discloses just one element of the set's performance (the response of the IF system to a single signal) it is easy to see that this method does not give a true picture of adjacent-channel operation.

In determining actual adjacent-channel performance not only the IF selectivity, but also the desensitizing effect of the interfering signal and the transmitter noise spectrum are important.

As we have already seen with the 20-db quieting method of measurement, the curve ceases to be significant when desensitization starts. Even in the range in which desensitization does not come into play, the 20-db quieting curve merely serves to show that one receiver has more IF selectivity than another. In itself, it cannot answer the question of whether two systems must be 60, 80, or 100 db down at 30 kc. off resonance for adjacent-channel operation.

**Two-Signal Measurements:** The method of selectivity measurement incorporated in the IRE railroad and vehicular communication specifications

FIG. 2. SETUP FOR TESTING RECEIVER SELECTIVITY BY THE IRE 2-SIGNAL SPECIFICATIONS

* Radio Communication Engineering, Commercial Equipment Division, General Electric Company, Electronics Park, Syracuse, N. Y.

as approved January 13, 1949, provides a factual measurement of selectivity.

It consists of feeding two modulated FM signals into the receiver. The first is modulated with a standard IRE test modulation, 1,000 cycles with 70% of maximum rated system deviation (10.5 kc.) with an input sufficient to produce 12 db ratio of signal + noise + distortion to noise + distortion, as measured with a standard distortion analyzer. The interfering signal is modulated at 400 cycles with 70% of maximum rated system deviation, and the level increased until the ratio of signal + noise + distortion to noise + distortion drops to 6 db. This level expressed in db with reference to the 12 db S+N+D/N+D level is plotted against frequency to form a selectivity curve. Fig. 2 shows the test setup, while Fig. 3 presents the block diagram. The squelch should be disabled for these measurements.

A selectivity curve produced in this manner is shown in Fig. 4. This curve is an actual measure of the level of an interfering signal required to produce a 6 db reduction in the signal to noise ratio of a weak signal.

The selection of reference level and the deviation are arbitrary, but represent reasonable approximations to operating conditions. The 12 db S+N+D/N+D signal level is the IRE and RTMA sensitivity standard, and represents a little less than the input required for 20 db quieting. The 10-kc. deviation has already been selected for RTMA standard test signals, and is somewhat greater than the average deviation on speech through of 400 cycles modulation, and is governed by IF selectivity. Then desensitization starts, causing the IF gain to decrease, reducing the signal and consequently increasing the noise through loss of quieting.

Fig. 5 shows the selectivity of three receivers that correspond to the 20-db quieting curves A, B, and D. The figure of 100 db at ±30 kc. has disappeared. The curves bear out the field test results.

The top curve, for receiver D, is a further proof that extreme IF selectivity is of relatively little value. Measured by the 20 db quieting method, this receiver indicated 100 db at ±33 kc. At 60 kc. off frequency, however, it is essentially the same as indicated in curve A. Improvement in performance at 60 kc. off frequency can only be achieved by improvement in desensitization, and further improvement in desensitization is hard to realize.

Further field tests were made with receivers A and B with the desired signal and the interfering signal 45 kc. apart, representing the minimum spacing possible for adjacent channels under FCC Rules on frequency tolerance of transmitters. Both signals were voice-modulated, with peaks causing limiting in modulation-limiters set for 15 kc. deviation. Receiver A proved to be a little better than receiver B, whereas the curves in Fig. 5 would indicate receiver B should have been 6 db better than A.

This discrepancy is due to the second factor mentioned in discussing the shortcomings of the 20-db quieting selectivity measurement: that is, the noise spectrum

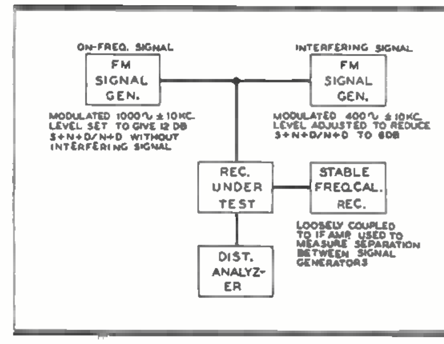


FIG. 3. SELECTIVITY TESTING BY IRE METHOD

signal frequency, the noise output decreases very little. Therefore, an adjacent-channel transmitter will produce noise-modulated sidebands on the desired frequency whose level is about 80 db below the adjacent-channel signal being received on the antenna. The question to be resolved is whether breakthrough of adjacent-channel modulation, desensitization produced by the adjacent-channel carrier, or on-frequency noise produced by the adjacent-channel transmitter will first cause interference in a given receiver. This can be determined by field tests, but it is desirable to have a laboratory method of predicting the performance of receivers. Such a method has been developed. It consists of three steps:

1. Preparation of sideband distribution curves for voice-modulated transmitters.

2. Preparation of receiver interference characteristics.

3. Graphical application of these curves to each other to determine the

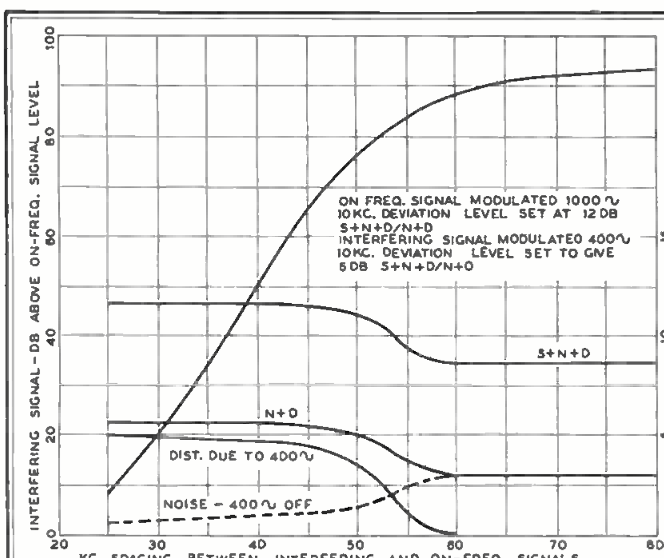


FIG. 4. INTERFERING SIGNAL LEVEL REQUIRED TO REDUCE THE SIGNAL-TO-NOISE RATIO BY 6 DB.

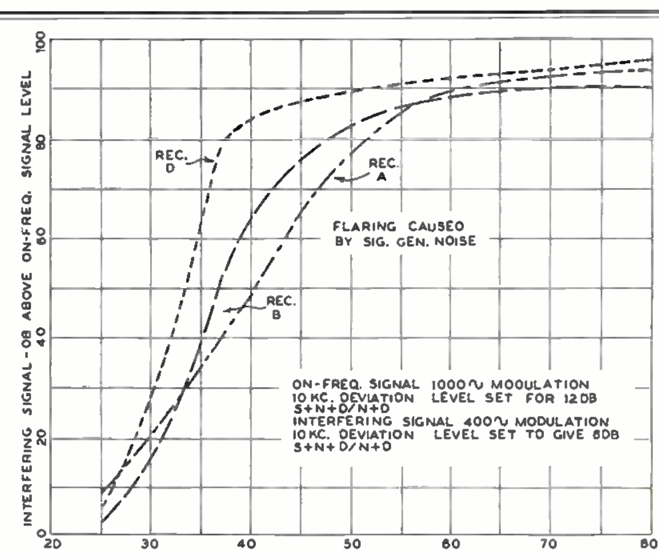


FIG. 5. IRE SELECTIVITY OF 3 RECEIVERS

with the peaks limited to 15 kc. The IRE test signal of 10.5 kc. is essentially the same.

An analysis of the audio ouput is shown on the lower part of the chart. This shows that at first the reduction in signal-to-noise ratio is due to break- of the transmitter producing the interference.

The noise spectrum of a typical transmitter is given in Fig. 6. It will be seen that at resonance the noise input is 75 db below the transmitter signal output. For several hundred kc. away from the source of adjacent channel interference.

**Sideband Distribution Curves:**

For a noise-free FM transmitter with no modulation limiting and sine wave modulation, sideband distribution can be calculated by means of Bessel Functions

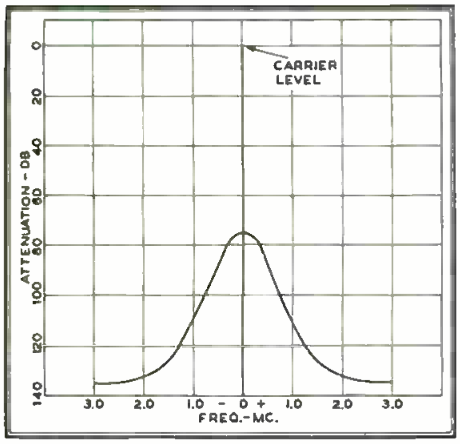


FIG. 6. TYPICAL TRANSMITTER NOISE CHART

and plotted in db with reference to the unmodulated carrier level against frequency in kc. from the carrier frequency. Fig. 7 gives such a curve for 360 cycles modulation and 10-kc. swing. For a practical transmitter this curve would be modified on the skirts due to the noise output.

Moreover, for complex wave forms of speech, the sideband distribution cannot be calculated. Since, in the practical case, an adjacent-channel signal would be speech-modulated, an empirical means of measuring the sidebands is necessary.

This was accomplished as shown in Fig. 8. The signal from the transmitter was fed into a shielded room through an attenuator and thence into a communication receiver modified to give a 100-kc. output from the second mixer. This was applied to a highly selective receiver through a second attenuator. The receiver was operated without regeneration, and the output from the plate of the detector was fed through an integrating network to a vacuum tube voltmeter. By this means, the RF level of the carrier, or of a narrow segment of the sidebands, can be measured as a DC voltage. In practice, the first attenuator was used to keep the signal from overloading the communication receiver. The second attenuator was used to maintain a constant output level and the relative levels of the sidebands determined by the attenuator readings.

To check the method of measurement, a signal generator modulated with 1,000, 2,200 and 3,000 cycles at ±10-kc. swing was connected in place of the transmitter. The measured sideband distributions checked the curves calculated from Bessel's functions within 2 db.

A tape recording of a test phrase was then prepared and fed into the microphone circuit of the transmitter. The modulation limiter was set for 15 kc. deviation, while the audio output level was set to give limiting on peaks of modulation. The resulting sideband distribution curve for normal speech is shown in Fig. 9. It will be noted that the skirts run off virtually horizontally at the 78-db level due to the transmitter noise.

### Interference Curves:

To use the transmitter sideband curve, a suitable receiver characteristic curve was prepared for each receiver to be investigated. The setup was made exactly the same as for the two-signal selectivity measurement, using the same desired-signal modulation and input level. For the interfering signal, a modulation of about 400 cycles per second was required to give a very sharp slope to the signal generator sideband distribution curve. The frequency of 360 cycles was chosen because it could be checked very accurately by comparison to 60 cycles. The deviation was set for 10 kc. A curve of interfering signal level in db, referred to the signal level for 12-db ratio of signal + noise + distortion to noise + distortion, versus frequency separation between desired and interfering signals was taken, using just perceptible audio interference as a criterion.

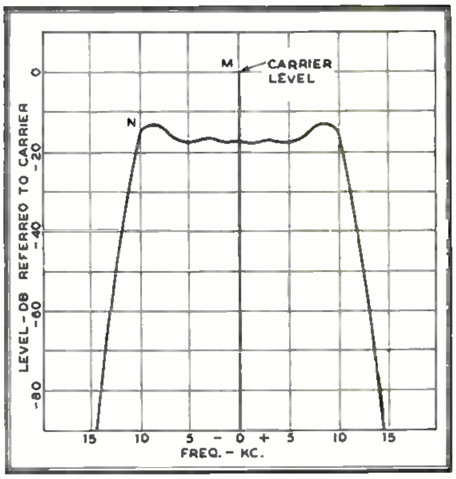


FIG. 7. CALCULATED SIDEBAND DISTRIBUTION

The 360-cycle sideband curve, Fig. 7, was then applied with its carrier center frequency set at some frequency such as 60 kc. The curve was raised until the point M marking the level of the unmodulated carrier just touched the previously-drawn curve. A small section of the arc on the knee of the sideband curve N was drawn. This was repeated for a number of points along the curve. By trial and error a curve could be drawn through the arcs representing the position of the knee of the sideband curve, such that, as the point M was moved up and down the original curve, N would just make contact with the new curve which can be called the Receiver Interference Characteristic. Such curves for receivers A, B, and D are shown in Fig. 10.

It will be noted that the curves have not been extended beyond the 60-db level. The curves are limited at this point because the threshold of just perceptible audio interference was masked by noise for higher input levels.

This noise interference was due to the noise output of the signal generator which, although considerably lower, relative to signal, than for a transmitter, still causes interference in the receiver under test before desensitization takes effect. If the noise was not present, the curves would level off at a value above 70 db.

### Use of the Curves:

The Receiver Interference Characteristics are basic receiver characteristics against which the sideband distribution curves can be applied for any transmitter at any given separation from the desired signal, with any sine wave or complex modulation such as voice with any desired deviation, to determine the nature of the interference produced and the level necessary to give just perceptible interference.

Fig. 9 represents the sideband distribution with the modulation of most practical interest, that is, normal voice modulation into a transmitter with the modulation limiting correctly set for 15 kc. If this is applied to the Receiver Interference Characteristics, Fig. 10, at the ordinate representing 60 kc. from the desired signal and raised vertically, it can

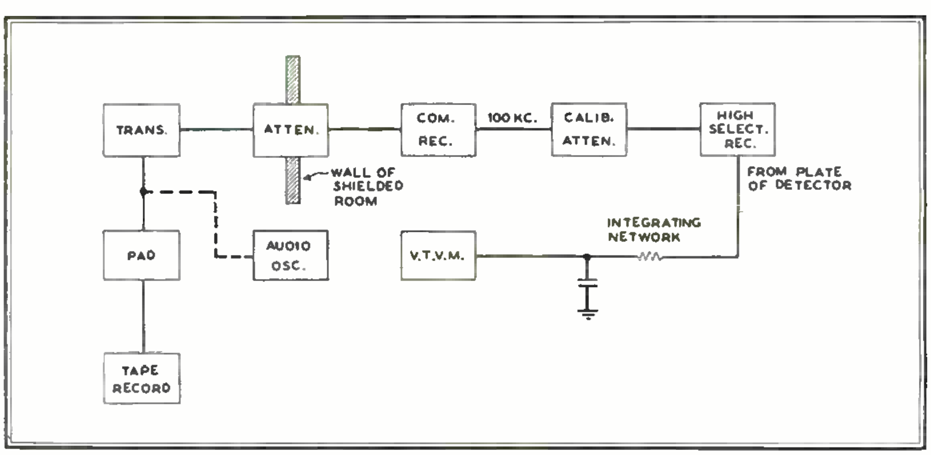


FIG. 8. SETUP FOR MEASURING TRANSMITTER SIDEBAND DISTRIBUTION WITH SPEECH AS INPUT

be determined whether desensitization due to the carrier of an adjacent channel signal, audio breakthrough due to its modulation, or noise due to its on-frequency noise spectrum will first occur. This can best be done by cutting out a transparent plastic template of the sideband distribution. If point M touches the Receiver Interference Characteristic, desensitization results; if any portion of the curve between N and O intersects, the interference characteristic there will be modulation breakthrough; and if the portion between O and P intersects the nose of the interference characteristic, noise will result.

First, the portion O-P intersects the nose of receiver D and then shortly after the nose of receiver B, but since the latter is broader, the area of interception on it increases rapidly, so that both receivers suffer perceptible interference at about the same level.

Finally, the nose of receiver A is intercepted. The slope O-N does not intercept any of the curves until the noise interference caused by section O-P has completely blanketed the receivers. Similarly, the carrier level, M, has not produced appreciable desensitization. Refer to dashed curves E and F on Fig. 10.

This graphical analysis predicts that receivers B and D will experience measurable interference at virtually the same interfering signal level, and that for receiver A it will take a somewhat higher level. Moreover, it indicates that the interference will be in the form of increase of noise and not modulation breakthrough. This was exactly the results that field test revealed.

Now let this technique be applied to the case of two transmitters operating at the extremes of the FCC frequency tolerance: that is, only 45 kc. apart.

We shift the carrier center line of Fig. 9 to the 45-kc. ordinate of Fig. 10, and repeat the procedure. It will be seen that noise and modulation interference will first appear on receiver B; then for a level of interference 6 to 8 db higher, modulation will occur in receiver A. Noise due to section O-P appears on receiver D. All the receivers will experience strong interference from noise and modulation before desensitization becomes appreciable. Here again these conclusions were borne out by field tests.

By these graphical means, therefore, a powerful means is available for determining the relative adjacent-channel performance of receivers.

### Design Criteria:

From this graphical study of selectivity, we can set down the following design criteria:

1. At the present stage of the development transmitter noise is the limiting factor in adjacent channel operation.

2. If means to reduce transmitter noise are found, receiver desensitization would then be the limiting factor.

3. With the above factors eliminated, a Receiver Interference Characteristic slope greater than that of the normal voice-modulation sideband curve results in no increase in adjacent-channel rejection. Since this slope of Interference Characteristic is determined by the IF selectivity, even if means of greatly reducing transmitter noise and receiver desensitization were found, there would be no value in increasing the IF selectivity of a receiver appreciably over that of receiver A with the present 60-kc. channel spacing unless means are found to increase the slope of the transmitter sideband distribution.

4. The bandwidth of the IF system at the nose should be made as narrow as possible consistent with good intelligibility, while maintaining reasonable allowances for drift due to temperature variations and for differences in setting of receiver and transmitter frequencies.

### Measuring Receiver Bandpass:

The graphical study of selectivity indicates the desirability of reducing the bandpass of the receiver, but it does not provide a measure of its adequacy in receiving the desired signal. In the past, an attempt to specify this has been made by specifying a minimum bandwidth for the 6-db points on the 20-db quieting selectivity curve.

It can be realized readily that a specification at the nose of the curve has nothing to do with selectivity, which is the ability of the receiver to accept one signal and reject the other. The purpose of such a specification is to insure that the bandpass of the receiver is sufficient to accept the desired signal without distortion, and with sufficient allowance for drift.

Selectivity and bandpass requirements should be stated separately. Obviously, a two-frequency measurement is not necessary, and is not desirable for a band width measurement. However, a modulated signal is necessary to give a true picture of the bandwidth.

As a start, the sensitivity of the receiver should be specified by the RTMA and IRE definition rather than by the 20-db quieting method which uses an unmodulated signal. This defines the sensitivity as a minimum value of a signal modulated with 1,000 cycles and 10-kc. deviation that will produce at least 50% of the receiver's rated audio power output with a ratio of signal + noise + distortion to noise+ distortion that is 12 db or better. This defines sensitivity in terms of a usable signal.

What is being sought with a specification bandwidth at 6 db? It is desired to establish how far the received signal

(Continued on page 38)

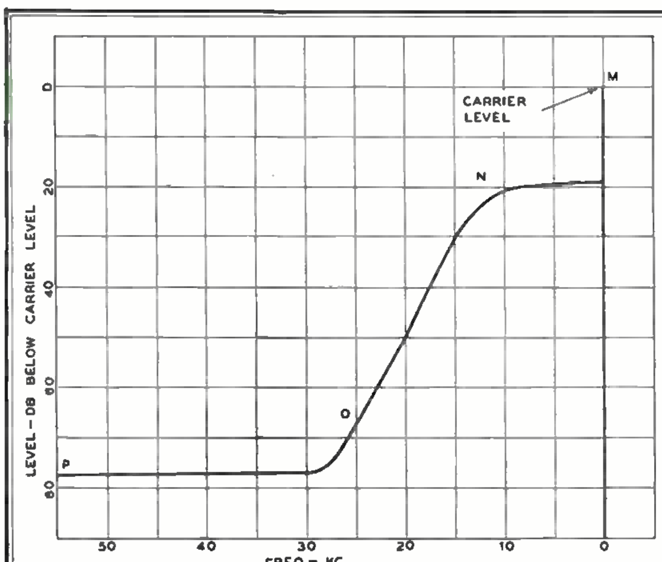


FIG. 9. SIDEBAND DISTRIBUTION CURVE FOR NORMAL SPEECH MODULATION

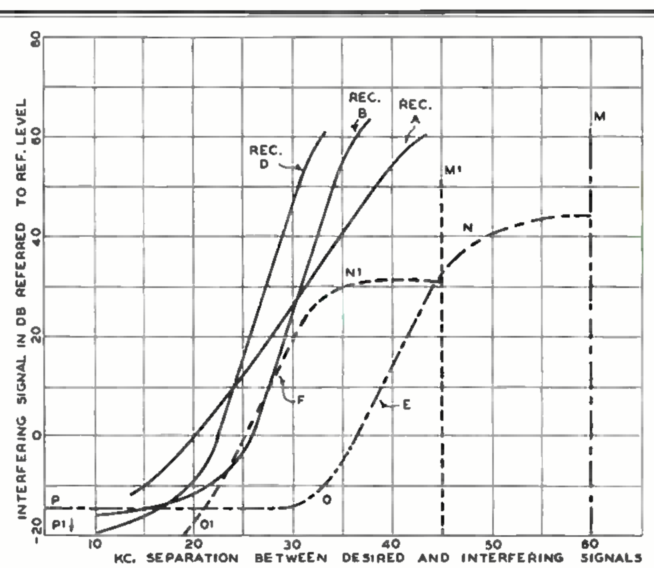


FIG. 10. DETERMINING MINIMUM LEVEL OF INTERFERING SIGNAL

# SPLICING RIGID COAX

## HOW TO SOLDER JOINTS IN RIGID COAXIAL CABLE TO OBTAIN BEST RESULTS — *By* C. RUSSELL COX*

MAKING joints in rigid air-dielectric cable is tedious and time-consuming at best. However, as with all mechanical operations, there is an efficient way of doing it that insures uniformly good results. This method is shown in the accompanying step-by-step illustrations.

FIG. 1. Cut the ends of the outer conductors 1 1/16 ins. from the outside edge (edge toward splice) of the last insulator. Use a cutting and grooving tool or a standard tubing cutter.

*Vice President, Andrew Corporation, 363 East 75th Street, Chicago 19.

FIG. 2. Cut the inner conductors ¾ in. longer than outer conductors. Be careful not to use too much pressure on the cutter or the conductor will crimp, making it difficult to insert the inner connector.

FIG. 3. Remove rough edges from both inner and outer conductors. Use a dull knife or scraper.

FIG. 4. Polish all surfaces to be soldered with garnet cloth.

During steps 1, 2, 3, and 4, be sure that no copper dust or particles enter the cable. A small piece of rag wrapped around the inner conductor will provide this protection. Tilting the cable slightly downward will help also.

Use soft solder and an acetylene and air torch with a small flame for tinning and soldering. Second choice is a gasoline blow torch with a small flame. Do *not* use acetylene and oxygen. Use only rosin flux, and do not allow the flux to burn. If it ignites, blow it out.

FIG. 5. Tin the outer conductors from 1¼ ins. from the end to ¼ in. from the end. Do not tin the last ¼ in. Wipe off excess solder and flux. Slide the outer connector over the end of one outer conductor and mark the outer conductor 1 3/16 ins. from the end. This mark will be used later to center the outer connector.

FIG. 6. Soft-solder the inner connector to the inner conductors as shown. Use a very small flame on the soldering torch. The ends of the inner conductors should be flush against the shoulder on the inner connector when joint is completed. Wipe away excess flux and solder.

FIG. 7. Slide the outer connector in place with one edge over the centering mark made in step 5. Optional: Tack the edges of the outer connector to the outer conductors with solder and roll grooves in the outer connector, ⅞ in. from each edge. These grooves strengthen the joint mechanically and prevent solder from flowing into the cable.

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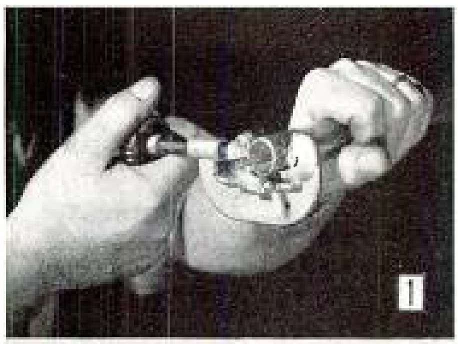
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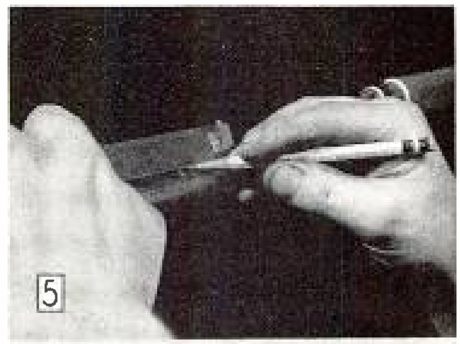
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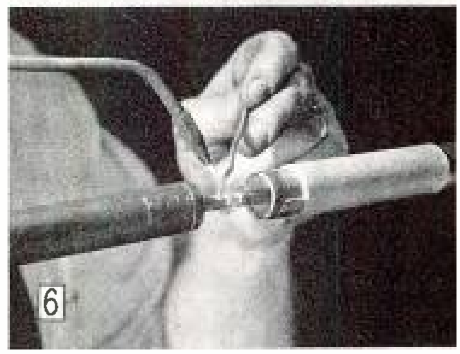
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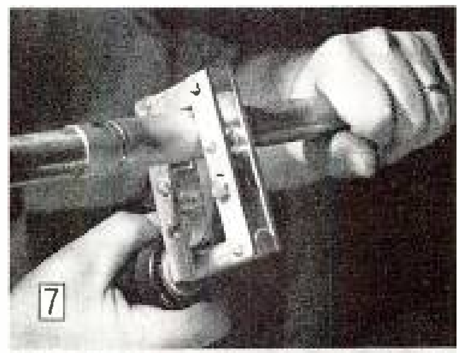
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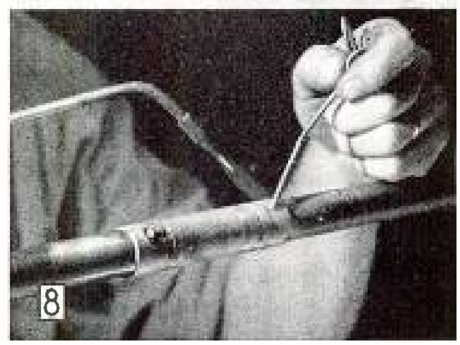
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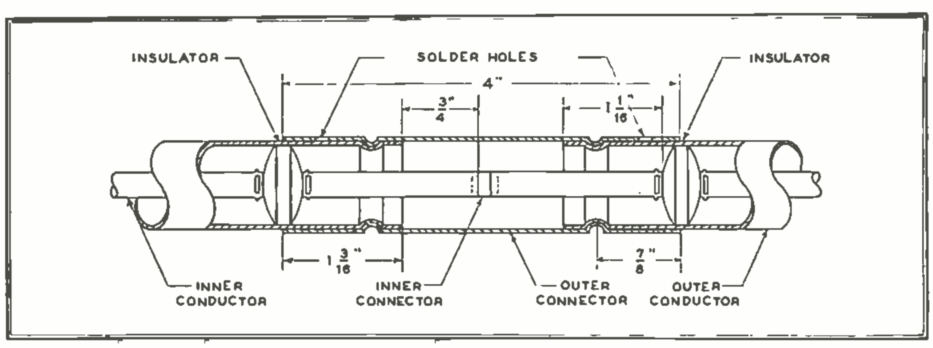



FIG. 9. CROSS-SECTION OF THE COMPLETED JOINT. GROOVES ARE HELPFUL BUT NOT REQUIRED

# FM RADIO CUTS RAILROAD COSTS

## HOW THE USE OF MOBILE AND PORTABLE 2-WAY FM EQUIPMENT INCREASES EFFICIENCY AND IMPROVES SAFETY FOR THE RAILROADS — *By* T. S. EADER*

THE utility of radio contact with moving trains has been long known, but only recently has equipment designed specifically for this application been available. Now, in these days of high labor and maintenance costs, it is almost impossible for a railroad to meet competition successfully without extensive 2-way radio facilities.

**Background of Railroad Radio:**

The first railroad radio system was installed in the early 1900's on the Delaware, Lackawanna, and Western Railroad. Operating at 300 kc., the one-way CW system was used for only a short time. It was troublesome and noisy, and met with a general lack of interest from other railroads.

Not until the first years of World War II was interest renewed in radio for railroad use. By then. compact. rugged, and dependable FM transmitter-receivers were available. Some railroads lost no time in adopting 2-way radio once the tremendous improvements it brought in safety and efficiency, due to more closely-coordinated communication, were realized. Indeed, railroad employees found many applications for 2-way units. both portable and hand-carried, that neither the owners nor the radio manufacturers had anticipated. With postwar improvements in equipment, more and more railroads are finding radio indispensable to their many operations.

**Freight Yard Applications:**

Primary justification for the extensive railroad use of 2-way radio is the dollar savings it provides through increased efficiency. Consider the use of radio as applied to freight yard service. Many different operations, all inter-dependent and all of which must be carried out simultaneously, are under the direct control of the yard master. It is his responsibility to coordinate the activities of his yard so that men and materials are used most efficiently, and to see that priority jobs are taken care of first.

Formerly, the yard master gave each locomotive crew a work order at the beginning of the day, arranged so that there would be minimum time lost between jobs. But a freight yard is a highly fluid organization, and the general plan is often changed to expedite specific jobs as the need arises. Without radio communication such changes make it necessary to wait for the crews to call in on routine checks, or else to send a runner to locate the crew or crews required for the special job. These plan changes alone warrant the use of 2-way radio, for with constant radio contact. the yard master has his motive power and crews under his control at all times.

Figs. 1 and 2 show a typical locomotive installation. Note the top-loaded antenna in Fig. 1. The roof of the locomotive serves as a ground plane.

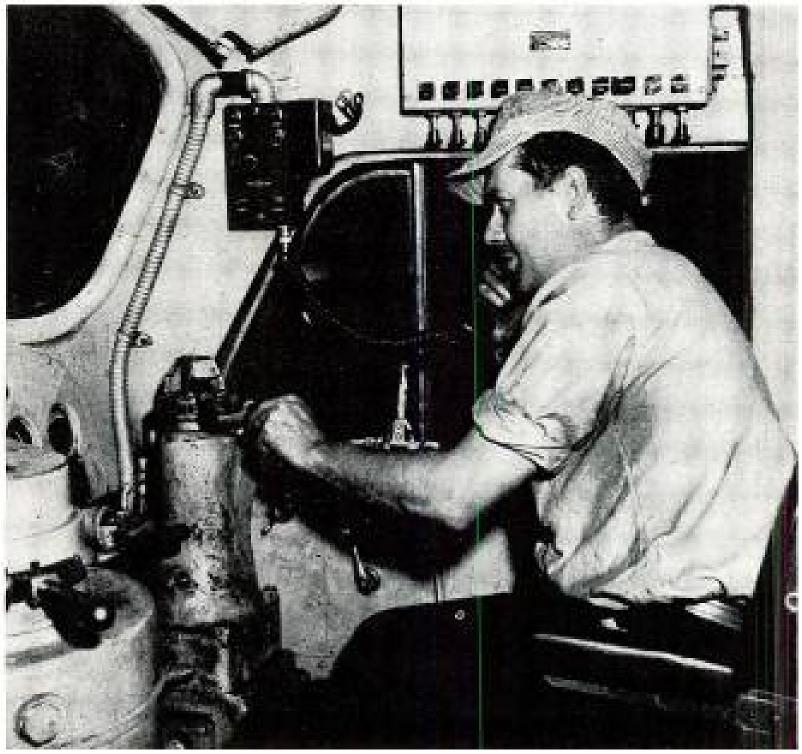
Other important yard applications are shown in the accompanying table.

**Main Line Radio:**

Present main line radio systems are comprised of: 1) Engine-to-caboose 2-way units for communication between the engineer and conductor, 2) Portable transmitter-receivers for communication between crew members while the train is stopped, 3) Mobile units for communication with wayside stations which are tied together with wire lines and operated locally or remotely by dispatchers, and 4) On some railroads, passenger telephone service.

A way station which can be operated remotely or locally is shown in Fig. 3. This is one of 8 such stations located in towers and yard offices along the 70-mile stretch between Fairmont. West Virginia, and Connellsville, Pennsylvania. The tower and antenna in Fig. 4 are at Springfield. Missouri, location of a base station for the Frisco Lines. A closeup

*Sales Engineer. Bendix Radio Division. Bendix Aviation Corporation, Baltimore 4, Maryland.

FIGS. 1 AND 2. VIEWS OF A LOCOMOTIVE INSTALLATION. TOP-LOADED ANTENNA ON ROOF MUST BE PHYSICALLY SHORT TO CLEAR UNDERPASSES

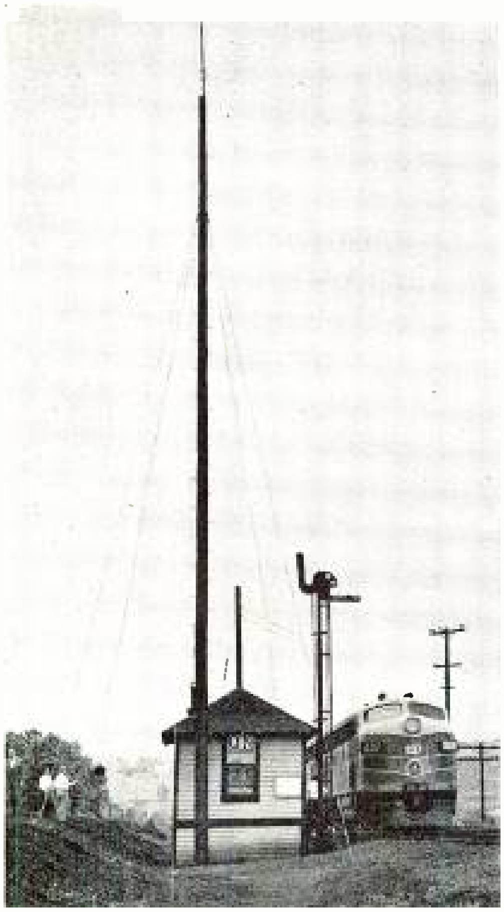


FIG. 3. WAY STATION FOR REMOTE OR ATTENDED OPERATION.

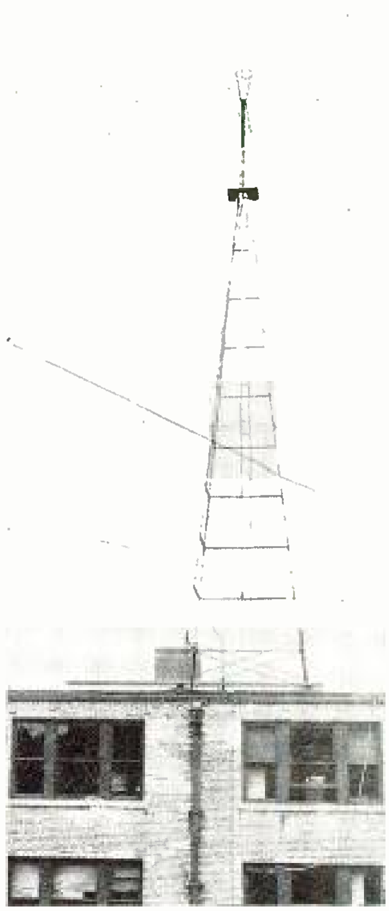


FIG. 4. BASE STATION ANTENNA TOWER.

FIG. 5. VIEW OF A WAY STATION ANTENNA

of a Baltimore and Ohio base station tower can be seen in Fig. 5.

Fig. 6 is a block diagram of an unattended wayside station. When a mobile unit initiates a call, a special audio tone superimposed on its carrier causes the audio output of the way station receiver to be bridged across the dispatcher's telephone line. The dispatcher, answering the call, presses a foot switch which sends the proper tone back to the unattended station. Then he actuates his press-to-talk switch, which operates the remote transmitter. As long as he holds the press-to-talk switch, the mobile selector at the remote station is held in the LINE ON position and the dispatcher can talk over the remote transmitter. However, upon release of the press-to-talk switch, the circuit is broken.

When the dispatcher at a base station originates a call through a remote way station, he must use a conventional selector unit to obtain the correct way

### RADIO COMMUNICATION FOR YARD OPERATION

1. Coupling or uncoupling can be carried out in bad weather, when hand-signals cannot be seen, by using portable transmitter-receivers between ground man and engineer.
2. Yardmaster can be notified by crews upon completion of assignments so that he can arrange jobs more efficiently. No time is lost by crew while waiting for further orders.
3. When several small yards are located in one city, one yardmaster at a central location can handle all yards simultaneously.
4. In case of difficulties, one engine can notify others immediately, thus preventing possible accidents.
5. Departures from yards can be speeded up, as yardmaster can inform engineer when conductor has waybills.
6. Engine trouble can be reported and repaired faster.
7. Helper engines can be obtained and used more quickly.
8. Knowledge of engine location permits crews to be changed by automobile rather than returning engine to yard.
9. Some delays at interlocking plants can be eliminated by knowing where trains are. Tower man can often permit switcher or transfer train to proceed if he knows how long it will take to clear interlocking plant.
10. Special movements for shippers can be expedited.
11. Delays caused by derailments or damage to cars or cargo can be minimized.
12. Urgent requests for special types of empty cars can be sent to all engines, whose crews can be on lookout for them.
13. When additional work is needed in isolated areas, crews can be requested to work overtime without time lost due to their returning to yard to end normal trick.
14. Yardmaster can clear switch leads quickly for emergency use by through trains.
15. Bad track can be reported immediately.
16. Yardmaster can be advised when train clears main line.
17. Sickness or accidents can be reported and assistance obtained sooner.
18. Car checkers can call car numbers directly to clerk. Eliminates time required to fill in card and deliver to clerk. The checker need not return to yard office.
19. When emergencies of any sort arise, car checker can go to trouble spot and provide communication from there to yard office. Decisions can thus be made faster and less time is required to get back to normal operation.

### RADIO COMMUNICATION FOR HUMP YARDS

1. Control points can be located in hump foreman's office and in retarder towers, to provide intercommunication as well as control. Engineers can be advised exactly how much to increase or decrease speed.
2. In many cases, humping can be continued in stormy or foggy weather.
3. Extra loudspeaker can be placed outside hump foreman's office to pass on information to pin puller.
4. Engineer can be directed to stop, slow down, or back up if couplings are fouled or other troubles occur.

### RADIO COMMUNICATION FOR MAIN LINE OPERATIONS

1. When troubles occur, conductor need not walk to block telephone to call wayside operator. With radio, notification can be made immediately. Also, other trains within 15-mile radius can be informed, and can take suitable precautions.
2. Speeds can be arranged at last minute to insure running meets at sidings.
3. Poor track conditions can be reported immediately.
4. Broken trains or derailments can be reported and repair crews dispatched quickly.
5. Crossing accidents can be reported; police and medical assistance can be expedited.
6. Helper assistance can be requested.
7. Conductor can correct waybill discrepancies by radio, eliminating delays at stops.
8. Wayside personnel can report hotboxes, dragging objects, or shifted cargo via portable equipment.
9. Train crews can request fuel, water, or other supplies before arrival, reducing time at stops.
10. Conductor can advise engineer when it is necessary to slow or stop train, so that brakes can be applied from forward end first. This reduces possibility of train breaks.

HERE IS A PARTIAL LIST OF SOME YARD AND MAIN LINE RAILROAD APPLICATIONS FOR PORTABLE AND HAND-CARRIED 2-WAY RADIO EQUIPMENT station. Operation is then the same as before, except that he must ring off the way station when the call is completed.

One or two dispatchers can be connected to the remote way stations, or the stations can be operated manually, Indication is provided at base and wayside stations to show when the radio circuit is busy.

Fig. 7 shows equipment used at a railroad base station being given a laboratory test by C. E. Cressman of Bendix. At the right, Fig. 8, is the author with equipment required for a locomotive or caboose installation.

The FCC has granted permission, in Rules effective Sept. 24, to construct relay stations for the purpose of extending the range of communication between railroad mobile units.[1] Thus, in cases where the need for such relay stations can be shown, wire lines will not be required for train-to-train or train-to-dispatcher messages.

Portable transmitter-receivers find wide use also in main line radio communication. They provide on-the-ground contact between crew members in cases of forced stops, so that all members can be advised of the trouble immediately.

### Equipment Design:

Equipment for railroad service must be of extremely rugged design. Conventional vehicular units simply will not stand up under the shock, vibration, temperature variations, humidity, and dirt encountered in typical railroad installations.

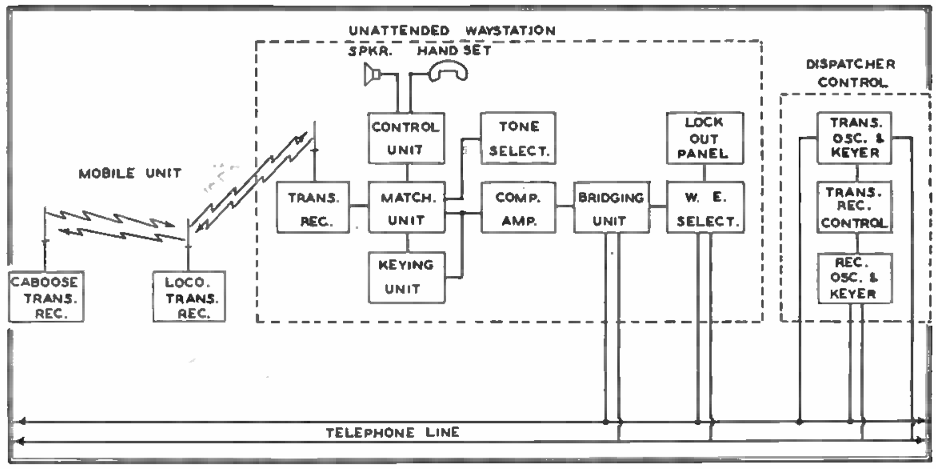



FIG. 6. BLOCK DIAGRAM OF A WAY STATION INSTALLATION FOR LOCAL OR REMOTE OPERATION

Consider the shock and vibration requirements alone. In no other service are the vibration amplitude and the instant shock magnitude equalled. A train of 100 box cars has a total slack in couplings of 600 ins. Therefore, when starting the train, the locomotive may have moved 50 ft. before the last car has moved at all. Cars at the end of the train are accelerated suddenly from zero to 5 or 6 mph. Under shocks like this draw bars, designed to withstand shocks of 90 *g*, frequently break in two.

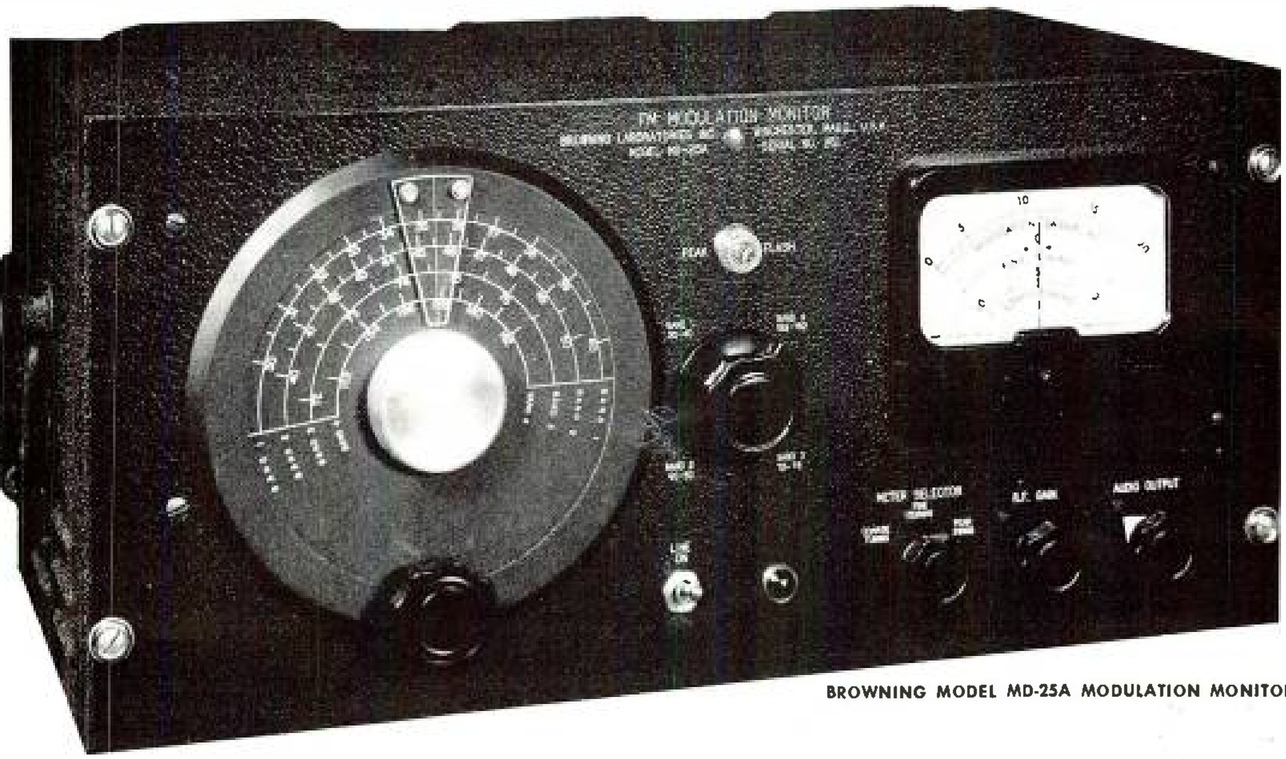
Bendix engineers, working on this problem, designed elaborate shock mounts to cope with this condition, but that was only a partial solution. More important, it was found, was designing all components so that they would fit close to the chassis. Thus, components of considerable mass still have low moments of inertia with respect to their mountings.

Power supplies presented some problems. It was finally decided best to incorporate a 110-volt AC power supply with the transmitter and receiver inside a strong metal case. These units can be used directly on power lines at base and wayside stations. On a locomotive, the 32, 64, or 110-volt DC is converted to AC by means of a rotary converter or a vibrator. A 12-volt battery with an axle-driven generator is installed with a vibrator unit on a caboose.

In 1949, the FCC assigned 41 channels, between 159.51 and 161.91 mc., to railroad use. In addition they were allocated 8 channels between 453.05 and 453.75 mc. Initially, the roads were very slow to make use of these facilities. Last year, however, very considerable orders were placed for railroad radio equipment, and projects to be completed in 1952 will probably represent an investment upward of $5 million.

FIG. 7. BASE STATION EQUIPMENT BEING GIVEN FINAL TEST. FIG. 8. HERE ARE ALL PORTABLE UNITS REQUIRED FOR A TRAIN INSTALLATION

[1] See "Mobile Radio News & Forecasts," by Jeremiah Courtney, page 20, this issue.




BROWNING MODEL MD-25A MODULATION MONITOR

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THERE are several precision-type modulation monitors that meet FCC requirements for checking the modulation of fixed and mobile transmitters.[1] But before you decide which type you will buy, be sure to get an answer to this question:

"If I need to check modulation at some additional frequency, can I do it with this meter, and will it involve additional expense?"

If you choose a BROWNING Universal Modulation Monitor, the answer is simple, because this instrument is a truly *universal* type. It is not limited to use on one or two specific frequencies. Instead, the BROWNING model MD-25A can be used to monitor *all* frequencies on *all three communication bands!* Yet modulation checks can be made as accurately as with an instrument designed for single-frequency use.

Equally important is the fact that the very moderate price of the BROWNING Monitor makes it positively extravagant to buy an instrument good for one channel only, that must be returned to the factory for changing to a different frequency, and that must be rebuilt if you need even one additional frequency. For complete details on the MD-25A Universal Modulation Monitor, write:

[1] FCC Rules require that each fixed and mobile transmitter in every radio system be checked for modulation every 6 months, and whenever an adjustment is made that might affect the modulation. Records of these tests must be entered in the station log, where they can be seen by the Radio Inspector.

## Browning Laboratories

700 MAIN STREET, WINCHESTER, MASS.

**In Canada: Measurement Engineering, Ltd., Arnprior, Ont.**

### MD-25A SPECIFICATIONS

Precision measurement of modulation swing at all frequencies in the bands from 30 to 50, 72 to 76, and 152 to 162 mc.

Frequency swing can be read directly on 4-in. panel meter. Measurements can be made on signals of less than 1 millivolt at the antenna terminals.

Flasher indicates instantaneous peak modulation in excess of 15 kc.

Voltage-regulated supply for local oscillator and metering circuits. Operates on 115 volts, 60 cycles.

Ventilated, rigid steel cabinet, of black wrinkle finish, is 9 ins. high, 20½ ins. wide, 12 ins. deep. Weight is 40 lbs.

**BROWNING LABORATORIES, Inc.**
**700 Main St., Winchester, Mass.**

Please send me technical details and prices on the following Browning precision products:

☐ MD-25A Universal Modulation Monitor
☐ Standard Frequency Meters for Mobile Systems

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# FUTURE FAILURE WARNING ALARM

## SIMPLE UNIT PROVIDES AN AUDIBLE WARNING OF IMPENDING TRANSMITTER FAILURE BY MONITORING CRITICAL-CIRCUIT VOLTAGE — *By* J. K. KULANSKY*

UNATTENDED remote transmitter failures in mobile, point-to-point, or relay systems invariably cause serious inconvenience and, in many cases, severe financial losses during the time it takes a maintenance man to reach the remote location and repair the trouble. A device which can give a warning at the control point in case of impending equipment failure, so that a man can be dispatched to the remote location before actual failure occurs, should be welcome to those who depend on uninterrupted functioning of communication transmitters. Such a fault alarm has been developed.

This device can be utilized also to send an alarm when a motor-driven emergency generator cuts in, as a warning of gasoline consumption and of power-line failure. With so many remote transmitters and receivers being used for an increasing number of special control and signalling purposes, many other applications will be found.

*Data Transmission Engineer, Hammarlund Manufacturing Company, Inc., 460 W. 34th Street, New York City.

**Principle of Operation:**

The Hammarlund low voltage dropout warning alarm, designated RSCTR-1A, is intended to monitor any critical voltage in a radio transmitter installation or other equipment, such as the starting-battery for an emergency engine-driven generator, and to provide a warning signal when the voltage drops below a predetermined level. This signal either modulates the transmitter or is applied to the telephone line running from the operating headquarters to the transmitter. Emission of a power-supply or a power-amplifier tube, for instance, often decreases gradually as the tube goes bad. The warning alarm can be used to detect a decrease in emission long before it could be discovered by listening to the transmitter signal. The warning alarm has a dropout differential of less than 1 volt within its nominal operating range from 26 to 34 volts. Thus, when monitoring batteries, it can be set to send the warning signal if the batteries are discharged below the point at which they require recharging, and to cut off when the batteries are recharged.

The warning signal is a 600-cycle tone sent for a period of 1 second at 10-second intervals. In cases where more than one circuit is monitored, the tone frequencies can be separated widely enough for ready identification.

**Circuit Description:**

Fig. 1 is a schematic diagram of the warning alarm. Top and bottom views of the unit, which is designed to fit a standard rack, are given in Fig. 2.

The voltage to be monitored is brought to terminals 5 and 6 on connector J1. When switch S1 is in the OPERATE position, the voltage is impressed across K1, the threshold relay, and a voltmeter. Operating threshold, or dropout voltage, is controlled by variable resistor R27. This can be adjusted to cause operation of the alarm at any voltage from 23.5 to 34 volts.

When the monitored voltage falls below the threshold, K1 is deenergized.

*(Continued on page 32)*

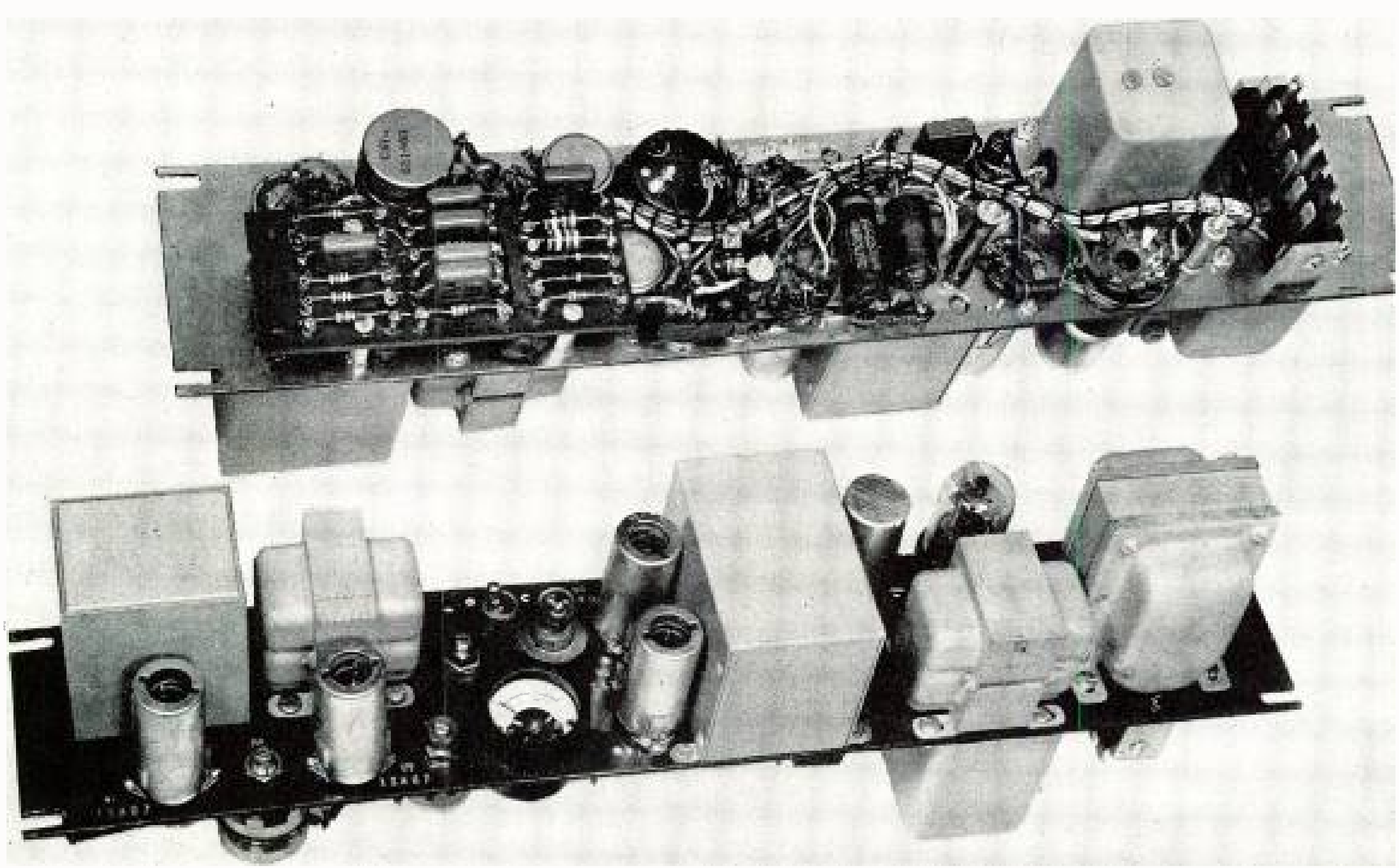

FIG. 2. TOP AND BOTTOM VIEWS OF THE WARNING ALARM. THE UNIT IS DESIGNED FOR A STANDARD 19-IN. RACK, AND IS ONLY 3½ INS. WIDE

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| Francis X. Foerch, 38 Beucler Pl., Bergenfield, N. J. | 1st Phone | 38 |
| S/Sgt. Ben H. Davis, 317 North Roosevelt, Lebanon, Ill. | 1st Phone | 28 |
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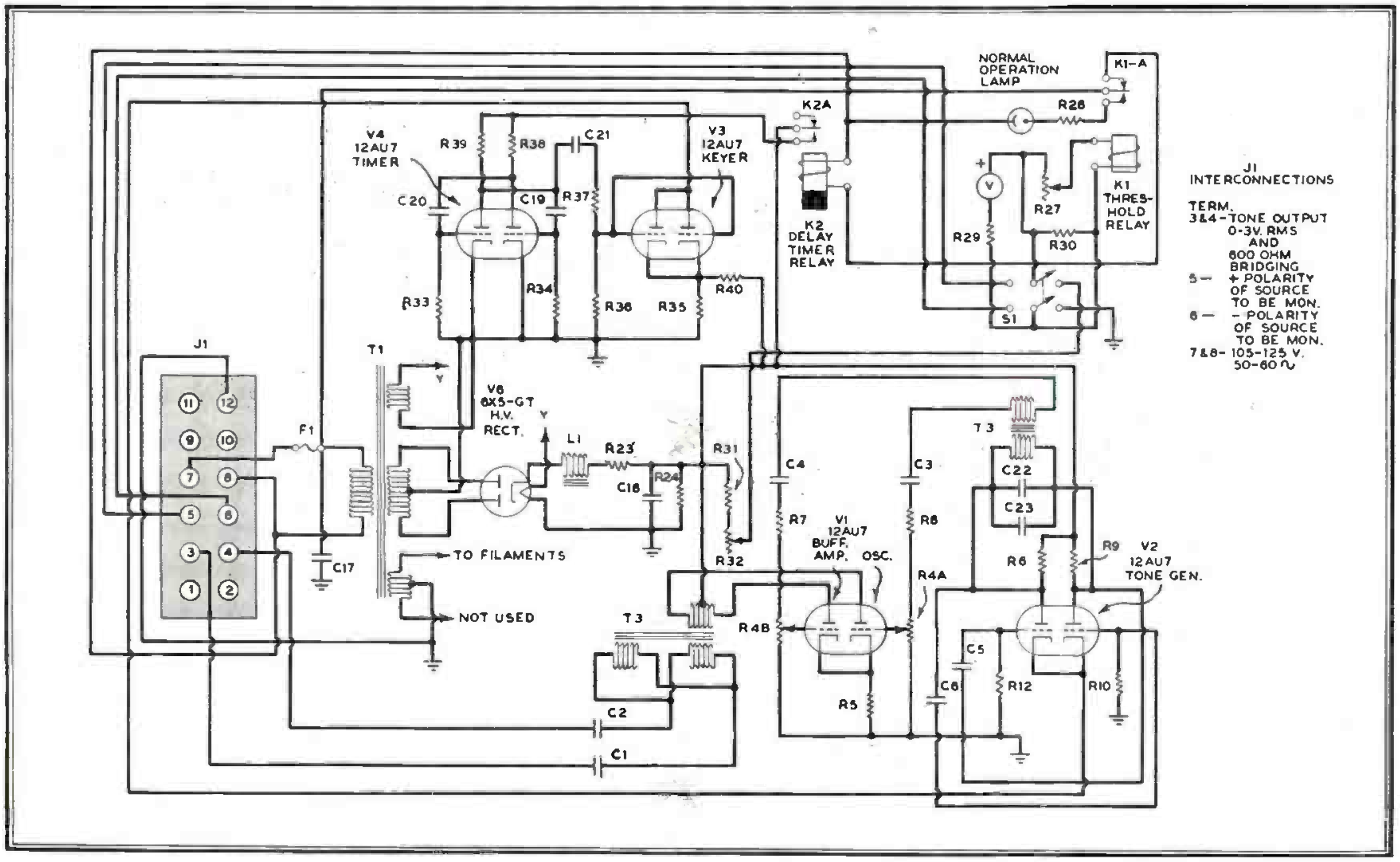


FIG. 1. SCHEMATIC DIAGRAM OF LOW-VOLTAGE DROPOUT WARNING ALARM, PROVIDING AN ADJUSTABLE, BALANCED AUDIO OUTPUT TO A 600-OHM LINE

*(Continued from page 30)*

This extinguishes the NORMAL OPERATION neon lamp and puts delay relay K2 across the AC power line. K2 can be adjusted for a delay of 1 to 30 seconds before operation. A long-delay setting is recommended to avoid transmission of warning signals for temporary low-volt-

*(Continued on page 37)*

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


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

Station WFAA

September 18, 1950

Eitel-McCullough, Inc.
San Bruno, California

Gentlemen:

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

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

Sincerely yours,
Carlos L. Dodd
Carlos L. Dodd

## ALMOST A YEAR AGO...

*this ad first appeared. Today WFAA and Eimac are still proud of their 3X2500A3 performance. A few weeks ago the first tube was removed from service (7000 hrs.). The other three are still providing top-notch performance.*

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

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

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


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The Power for R-F

Export Agents: Frazar & Hansen, 301 Clay St., San Francisco, California

**the 3X2500A3 is another Eimac contribution to electronic progress.**

269

## SPLICING COAX

*(Continued from page 25)*

FIG. 8. Solder the outer connector in place, using the solder holes for feeding solder to the joint. Heat connector and cable uniformly. Do not use an excessive amount of heat. Solder a fillet all the way around each end of the splice and be sure that the solder holes are closed with solder. If grooves are not used, be careful not to use an excessive amount of solder, since it may short-circuit the conductors if permitted to enter the cable. Wipe excess solder and flux from the joint. This completes the splicing operation.

## POINT OF VIEW

WE'VE all heard the phrases, "It depends on how you look at it" or, "It's all in your point of view" many times.

To TV broadcasters, the Japanese Peace Treaty Conference telecasts via Bell's West-East microwave link meant large audiences then, and the promise of a wider variety in programs when the link goes into steady operation. Engineers marveled at the picture quality, which was not noticeably deteriorated after 106 relay hops.

But what did Mr. John Public think of this spectacle, that the combined effort of so many in the radio industry had brought to his living room at such cost? Well, we'll simply reprint, without comment, an article by H. I. Phillips which appeared in the *New York World-Telegram and Sun:*

Our scouts are back from the United Nations' World Series at Frisco, which featured the no-hitter of Dean (Lefty) Acheson and the attempt of Joe Stalin to steal second with the bases full. The scouts' three definite observations on the performance of the Russians via television:

1. Gromyko set video back at least a dozen years.

2. The coaxial cable definitely killed the Moscow act. "There Is No Business Like JOE Business."

3. Through the Frisco telecasts the video industry discovered that in the Russians and their stooges, especially Stefan Wierblowski of Poland, it found the perfect commercial for a super deep-freeze unit.

If Gromyko had spent a life training to repel a video audience he couldn't have done better. He has already had offers to haunt Inner Sanctum, Suspense, wrestling at Ridgewood Grove, Uncle Limpy's Cabin and Dragnet.

On any new video show you look for novelty, but on the coast-to-coast telecast of the U. N. meeting you know Gromyko and his associates would put on the old horror hour or Moscow "Rowdy Broody" show.

One look at their stern, frozen faces and you realized Gromy had his own video smoke test: "Take a deep puff: don't inhale: now blow through your nose and say monkey wrenches are milder." When you look into the face of a Soviet performer on a video screen you know at once that you are not going to get a crooner, a funny story teller, a personality smile or an endorsement of any headache powder. The Russian delegation was a talent scout's nightmare. Every program ever put on radio or television by Messrs. Gromyko, Vishinsky, Malik & Co. has had one title, "Life Can NOT Be Beautiful."

At the opening of the Frisco show it seemed that Gromyko and Wierblowski were going into a video cooking program in which they would tell how to make a goulash by boiling the hopes of the world over a hot flame, flavoring with a barrel of vitrol, seasoning with a dash of invective and serving the dish on pitchforks.

Gromyko's facial expression could be a commercial for dead-end streets, international suspicions, trap doors, secret panels and any good anti-sleep pill. We could not escape the conviction that if the Russians got into a baseball world series they would insist on playing the

*(Concluded on page 35)*

## POINT OF VIEW

*(Continued from page 34)*

last inning first, making the batter face the catcher and interrupting every play with a commercial for vodka, red cabbage and sour cream. ("Doctors have examined a million vodka and sour cream users without one case of throat irritation, etc.")

Millions of Americans took one gander at Wierblowski doing his routine and exclaimed, "And they told me Lon Chaney was dead!"

## UHF-TV RECEIVER DESIGN FACTORS

A paper on TV receiver design modifications for UHF reception was delivered by W. B. Whalley, of Sylvania's Physics Laboratories, Bayside, N. Y., at an IRE symposium in the Franklin Institute, Philadelphia, on September 17.

Whalley cited the following receiver components as requiring particular engineering consideration: input tuner circuits, IF amplifiers, AGC circuits, and sync circuits. UHF receiver components which need not be redesigned include the video detector, the video amplifier, horizontal AFC circuits, the deflection and sound systems, and voltage-supply circuits.

Commenting on the TV receiver sections that do not require modification for UHF reception, Whalley restated his belief that 1N60 germanium diodes provide advantages for video detection because of their high forward conductance, low losses, low intrinsic capacitance and high back resistance characteristics.

"The intercarrier sound system," Whalley continued, "facilitates tuning and can give less audio noise between channels. This can be an important factor in UHF reception, because of the great number of channels and the wide spaces between those which are active in a given location."

To reduce the detrimental effects of rapidly fluctuating signals and interference caused by cross-modulation, Whalley stated that sync circuits would have to be especially good. "Cross-modulation may occur more readily at UHF," he explained, "because of the poorer discrimination against nearby channels, due to the limited number of tuned circuits."

Summarizing considerations in IF frequency selection, Whalley listed the following:

1) Image rejection. 2) Minimum power of beat frequencies between harmonics of the IF and the incoming signal. 3) Local oscillator radiation. 4) Noise factor. 5) Gain for a given number of stages. 6) Possible regeneration with low channels in the VHF band.

*(Concluded on page 36)*

## UHF-TV DESIGN

*(Continued from page 35)*

**Tuner Considerations:** Because of the large number of UHF channels, Whalley said, several schools of thought exist with regard to the mechanical operation of the UHF tuner. He classified possible mechanical designs in three groups including the continuously-tunable type; the semi-continuous or band-spread type, in which a switch selects UHF tuning zones and a dial is used to tune the channels in each zone; and selector switching, in which up to eleven UHF channels can be pre-set, and are then tunable with VHF channels by the same type of selector switch now being used.

Commenting on UHF tuners from the standpoint of tuning ease, Whalley stated that an accuracy of 1 part in 42,-000 is required for good sound on a double-IF UHF receiver. He implied that such accuracy would be hard to maintain with a standard selector-switch alone, which most people prefer.

Requirements for efficient UHF RF amplifiers, he stated, include the following: 1) Reduction of local-oscillator coupling to antenna, 2) Improvement in noise factor to increase the useful range of the transmitter, and 3) Provision for increased image rejection and reduced cross-modulation at the mixer.

While tube types suitable for RF amplifiers at reasonable prices are conspicuous by their absence, he suggested as having some possibilities planar grid triodes, such as the type 5768, and the small traveling-wave tube suggested by Robert Adler of Zenith. He also mentioned the new silicon diode mixer, type 1N82, as being of interest because of its noise factor which is better than that of germanium diodes.

## DUPLICATION

*(Continued from page 17)*

complete circuit diagrams, circuit constants, marginal relay settings, and all other pertinent information applicable to the particular transmitter for which unattended operation is contemplated. It is to be noted that although each installation is probably built about a certain piece of basic equipment, each application must show the exact installation for that particular transmitter.

"It is necessary to file at the same time a maintenance schedule, indicating precisely what service and maintenance will be carried out on the transmitter which is to be operated unattended. The maintenance schedule must be signed by the person responsible for carrying out such maintenance as laid down in the schedule. This maintenance schedule

*(Concluded on page 37)*

## DUPLICATION

*(Continued from page 36)*

will, of course, depend largely on the transmitter location, accessibility, and availability of trained personnel, but it must be satisfactory to the Radio Division before approval will be granted for unattended transmitter operation.

"When sufficient and satisfactory information has been submitted, approval may be granted for unattended operation, and the licensee may generally proceed with the installation of the necessary equipment and circuits. When installation and adjustment is complete, a certificate to that effect must be filed by the consultant responsible for the installation and adjustment, and thereafter no changes may be made in either the overall system or any adjustment without first getting approval by the Radio Division."

## MOBILE RADIO NEWS

*(Continued from page 20)*

communications. Interpretation will do much to facilitate cooperation of mobile radio licensees in the Civil Defense planning of their communities.

**Miscellaneous Developments:**

By general order, Commission has extended to November 1, 1952 Class 2 experimental licenses of common carrier stations operating in general mobile, TV pickup, TV STL, microwave relay, short haul toll, rural subscriber, repeater, domestic control, and developmental categories.

Part 18 Rules applicable to welding equipment using radio-frequency energy have been further suspended to January 31, 1952.

## WARNING ALARM

*(Continued from page 32)*

age disturbances.

At the end of the delay period, the contacts of K2 complete the plate circuit for the interval timer V4. This is a multivibrator with long time-constants. The right-hand section of V4 is alternately conducting for 10 seconds and non-conducting for 1 second.

V3, the tone-keyer tube, is in the cathode circuit of tone generator V2. A voltage-divider circuit across the power supply keeps V3 normally cut off. The 1-second positive plate pulses of V4, however, bring V3 abruptly into conduction, and make it a low cathode impedance for V2. Thus, V2 operates only during the 1-second ON periods of V4.

V1 is a push-pull buffer amplifier for the tone generator. Amplitude of the

*(Concluded on page 38)*

## WARNING ALARM

*(Continued from page 37)*

signal is adjustable by R4A and R4B from 0 to 3 volts RMS. A bridging transformer provides an output impedance of 600 ohms at J1 terminals 3 and 4.

When the monitored voltage rises to 1 volt above threshold, K1 is reenergized. This removes power from K2, opening the plate circuit for the timer multivibrator. The tone signals are then stopped.

**Calibration of K1:**

With S1 in the OPERATE position, the voltmeter reads the monitored voltage. When S1 is in the CALIBRATE position, the meter reads the calibration voltage determined by R32. To calibrate, S1 is put into the CALIBRATE position and the threshold adjustment R27 advanced to maximum. Then R32 is rotated clockwise until the neon lamp indicates that K1 is energized. It is then retarded until the lamp is just extinguished, at which time the meter reads the dropout voltage of K1. The settings of R27 and R32 are reduced in steps until the meter reads the desired dropout level as the lamp is extinguished. Then S1 is put back to the OPERATE position for normal monitoring.

**Power Requirements:**

The warning alarm operates with a single-phase AC input of 105 to 125 volts at 50 to 60 cycles. Power input is less than 50 watts.

## PERFORMANCE SPECS

*(Continued from page 24)*

can be off frequency without reducing the sensitivity more than 6 db. The 20-db quieting measurement does not give this. At best, it is a measure of IF selectivity and, as a matter of fact, usually comes out several kc. narrower than this.

If a signal 6 db above the IRE sensitivity level, as defined above, is fed into the receiver and then the deviation is increased until the ratio of signal + noise + distortion to noise + distortion falls to 12 db, the level for the RTMA sensitivity specification, the desired characteristic has been measured. The bandwidth at 6 db will then be twice the deviation. If the receiver selectivity is unsymmetrical, interference will occur at first on the narrower side, and the resultant deviation for 12-db S+N+D/N+D will be less than for a symmetrical characteristic.

This measurement of bandwidth takes into account both the reduction of signal level and the increase in distortion occa-

*(Concluded on page 39)*

## PERFORMANCE SPECS

(Continued from page 38)

sioned by moving off the center frequency of the receiver. If we consider that the RTMA standard test signal of 1,000 cycles and ±10 kc. swing represents normal modulation then ± (bandwidth-20)/2 is the allowance for drift.

The bandwidth is determined not only by the amplitude attenuation which is measured by IF selectivity measurements, but also by the phase shift characteristic. Of two receivers, the one with the wider bandwith as measured by IF selectivity may actually have a narrower bandwidth, due to the shape of its nose, when measured by a method employing a modulated signal and using signal-to-noise ratio as a criterion.

A square nose shape will introduce far more phase shift than a rounded one. and in FM systems abrupt phase shift results in distortion of the modulating signal.

For a practical figure, the bandwidth should not be less than 34 kc. at 6 db for 15 kc. maximum swing. The same method can be used at any other level at which it is desired to measure the bandwidth at the nose.

An alternative method to the one just outlined would be to feed in a signal of the same level, but keep the deviation at a fixed amount and then shift the frequency first to one side and then the other until the S+N+D/N+D is reduced to 12 db. The bandwidth is then twice the sum of the deviation and the smaller of the two shifts in frequency.

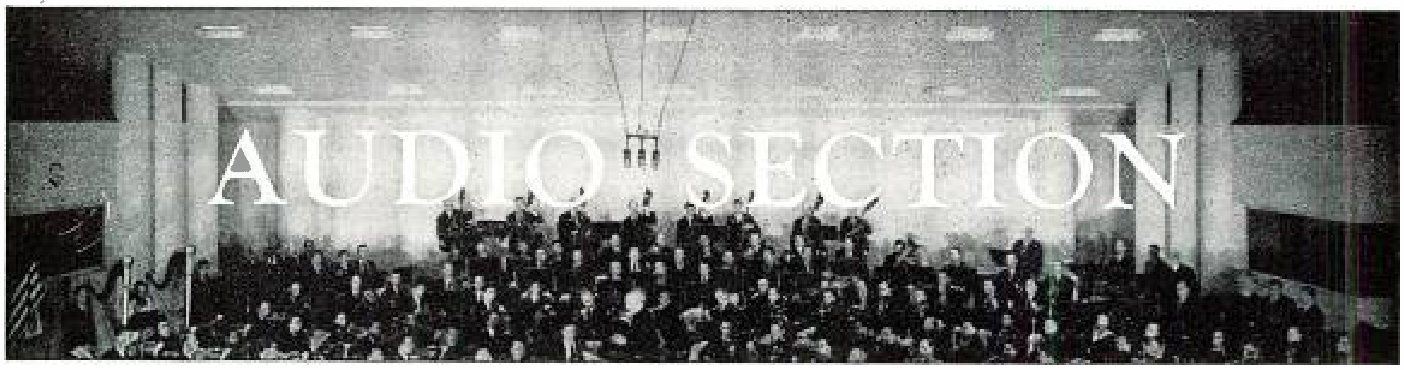
This method gives promise of being more precise, but it is somewhat more difficult to make and requires study to set the modulation to be used.

No matter which method is used to specify the minimum bandwidth at the nose for acceptable on-channel signal reception, the nose width should also be examined to determine if it is compatible with good adjacent-channel rejection.

The adjacent-channel performance of a receiver can best be indicated at the present time by use of the two-signal selectivity specification and a minimum nose width specification using the dynamic method of nose-width measurement described above.

To insure the best adjacent-channel performance, the nose width should be held as close as possible to the minimum specified to minimize the interference due to transmitter noise.

The author wishes to acknowledge his indebtedness to a number of his associates, particularly to Messrs. N. H. Shepherd and R. P. Gifford who were, in a large measure, responsible for the graphic selectivity analysis and to C. M. Heiden for his guidance of this project.




# A THREE-CHANNEL LOUDSPEAKER

## DESIGN CONSIDERATIONS IN THE DEVELOPMENT AND CONSTRUCTION OF THE FIRST INTEGRAL THREE-CHANNEL LOUDSPEAKER SYSTEM—*By* KARL KRAMER*

THE design of a completely linear sound transducer is one of the most complex and baffling tasks ever undertaken by engineers. Nevertheless, great progress has been made in the relatively short time since the loudspeaker was merely a headphone attached to a gooseneck horn. This article describes a loudspeaker design that brings the ideal closer to realization, and discusses some of the considerations involved in its development.

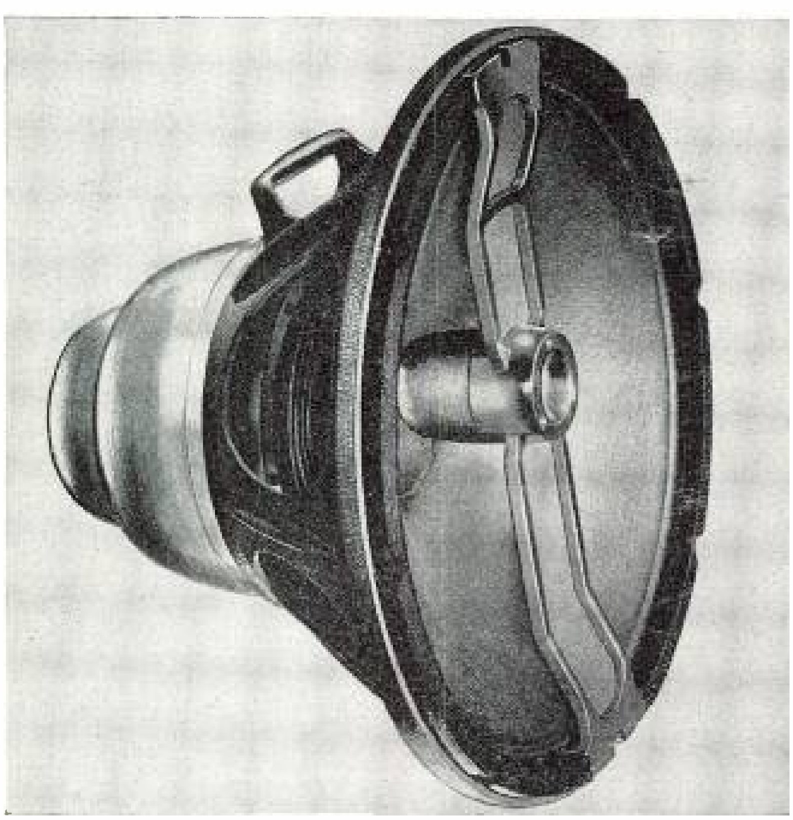
**Loudspeaker Development:**

In the very early days of sound reproduction, horn-type loudspeakers were used extensively. They were efficient, but quite limited in frequency range, particularly at the low end of the spectrum. The moving-coil, direct-radiator loudspeaker was an improvement, but was inefficient at the upper end of the scale. The performance of both types has since been considerably improved. However, it has been long known that fundamental design considerations dictate that the criteria for good response at the two extremes of the frequency spectrum are entirely incompatible.

The use of two loudspeakers in a dual-channel system was a long step forward, for each of the speakers was required to reproduce only a portion of the total sound-frequency spectrum. Such loudspeaker systems were used extensively in professional applications, but were often rather large and unwieldy. The wide-spread use of two-channel systems for general applications became practical with the advent of the coaxial type of loudspeaker, in which the speaker units were integrated into a single assembly of reasonable size and conventional physical form.

However, rapid strides have been made in recent years in signal source equipment, materials, and techniques. It is now possible to obtain low-distortion, wide-range program material from FM

*Technical Service Manager, Jensen Manufacturing Co., Chicago.



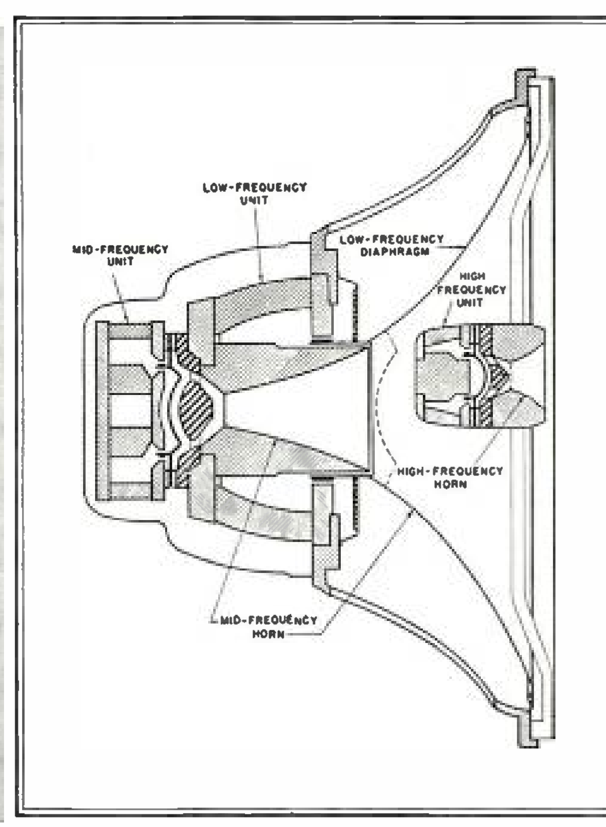



FIG. 1. TRIAXIAL SPEAKER ASSEMBLY, PROVIDING 3-SPEAKER PERFORMANCE AT VIRTUALLY POINT SOURCE. FIG. 2. SPEAKER CROSS-SECTION

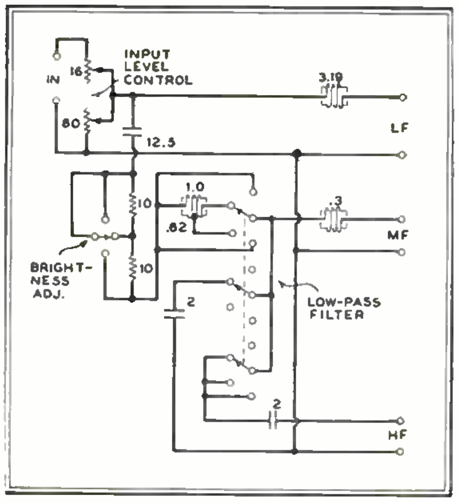



FIG. 3. SCHEMATIC DIAGRAM OF THE NETWORK

broadcasts, magnetic tape recordings, and microgroove phonograph records. As a consequence, there has been a demand for still better loudspeakers. The entire range of human hearing, with regard to both frequency and amplitude, must be reproduced. Also, in reproducing this wide range, even less distortion is tolerable than with previous systems encompassing a lesser range. A three-channel loudspeaker is a logical means of obtaining this increased range with reduced distortion. Such a loudspeaker has now been developed.

### General Description:

The Jensen G-610 Triaxial speaker, shown in Fig. 1, is a triple-channel system of unitary construction. It is comprised of three separate and distinct reproducing elements, each with its own voice-coil and diaphragm. All electrical dividing-network and control elements are assembled on a separate chassis, with plug-and-cable connection to the speaker array.

The nominal input impedance of this system is 16 ohms, which is a value suitable for direct connection to most high-quality amplifiers. Provision is made for the use of an impedance-matching transformer when necessary. A variable L-pad permits adjustment of the input level as desired. The input signal is then passed through the first dividing network section where the low-frequency range, consisting of all frequencies below 600 cycles, is separated for reproduction by the LF reproducing element. This is a direct-radiator type loudspeaker. The remainder of the signal spectrum, consisting of all frequencies above 600 cycles, can then be attenuated for optimum balance with the LF output. This facility is important, since it is in this frequency range that room reverberation characteristics vary widely, because of size and absorption differences.

The signal is then passed on to the second dividing network section. Here the mid-frequency range, consisting of all frequencies in the band from 600 to 4,000 cycles, is separated for reproduction by the MF reproducing element, which is a horn-type loudspeaker.

The signal spectrum remaining consists of all frequencies above 4,000 cycles, and it is fed to the high-frequency channel. A low-pass filter, adjustable in frequency, is inserted in this channel. This provides any degree of noise and distortion suppression that signal quality dictates. It is generally conceded that program quality is considered to be better when the bandwidth is reduced, providing distortion or noise content is thereby reduced. This is usually the case when reproducing marginal program material. The signal is then passed on to the HF reproducing element, another horn-type loudspeaker. The outputs of the three channels combine to give full-range reproduction.

The maximum frequency range detectable by the ear under laboratory conditions at very high levels extends from 16 to 20,000 cycles. This is a frequency ratio of over 1,000 to 1, or about 10 octaves on a musical scale. However, it should be remembered that the average frequency range of the human ear is somewhat less than this, and that usual listening conditions are much less favorable than those in the laboratory. Furthermore, the hearing range is reduced as the sound level is decreased.[1] Table 1 lists the three frequency bands discussed, their frequency ratios, and the number of octaves included.

This apparently arbitrary arrangement of channels will be discussed in some detail in the next section, which describes the three reproducing elements.

TABLE 1

| Channel | Band | Ratio | Octaves |
|---|---|---|---|
| LF | 16-600 | 37 to 1 | 5 |
| MF | 600-4,000 | 7 to 1 | 3– |
| HF | 4,000-20,000 | 5 to 1 | 2+ |

### The Mid-Range Horn:

Fig. 2 is a sectional view of the loudspeaker array. It will be noted that all three reproducing elements, the component loudspeakers, are incorporated in a single assembly. The most noticeable departure from custom is the arrangement of the MF loudspeaker. Here the typical horn-type driver unit is attached to the back of the LF magnetic structure, and the annular throat and initial section of its horn are formed in the core, or center pole, of that structure. However, the final portion of this horn is formed by the curved diaphragm of the LF unit. It can be seen that the shape of this diaphragm is a contiguous continuation of the shape of the initial section. This yields the largest possible horn mouth size, about 12¼ ins. in diameter. Obviously, no separate horn structure even approaching this size could be used in front of the LF radiating diaphragm without serious interference.

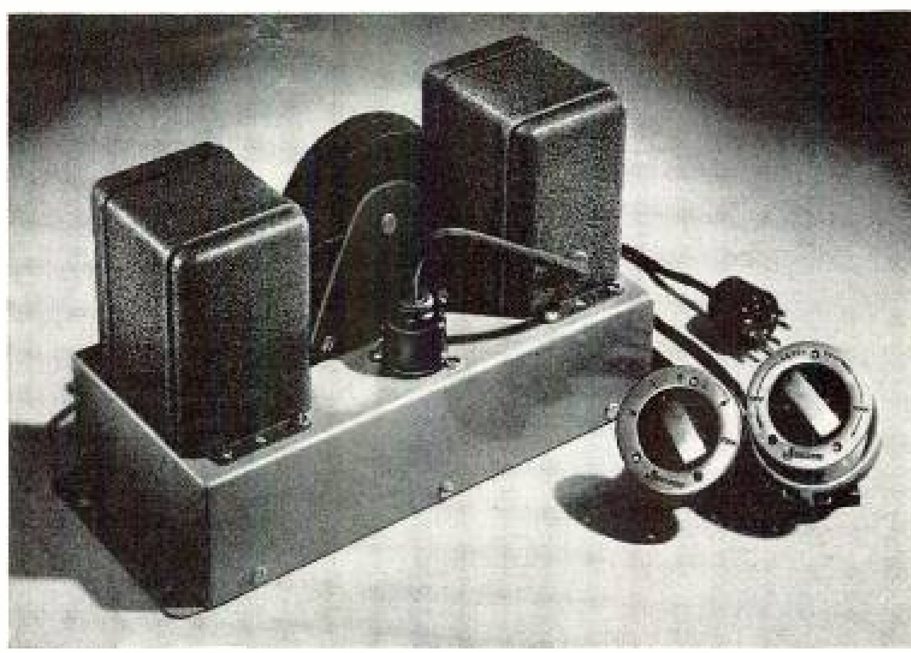


FIG. 4. THE 3-WAY CROSSOVER NETWORK CHASSIS, WITH LEVEL AND ROLLOFF CONTROL KNOBS

It will be recalled that the MF channel is allotted a frequency range extending down to 600 cycles, at which the wavelength is approximately 23 ins. Therefore, the horn mouth diameter at 600 cycles is 12/23, or about ½ the wavelength. Conservative horn design data indicate that the mouth diameter should not be less than 1/3 the longest

(Continued on page 42)

[1] See Jensen Technical Monograph No. 3 "Frequency Range and Power Considerations in Music Reproduction."

## LOUDSPEAKER

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wavelength. Thus, it is seen that this mouth diameter is more than adequate.

The discontinuity of the horn surface at the back of the LF diaphragm is of no consequence, since it is quite small in terms of wavelength for even the highest frequency of 4,000 cycles, which is approximately 3½ ins. Also, very careful measurements reveal no detectable intermodulation of the MF channel by the vibration of the LF diaphragm in its normal function.

In addition to mouth size, the horn contour is important. The hypex[2] family of contours has been shown to offer considerable advantages in constant-resistive loading, and such a contour was chosen. Horn contour also affects the shape of the radiated wavefront; the exact contour has been chosen to yield a wide angular distribution at the upper limit of 4,000 cycles.

The design of an excellent driver unit for the relatively narrow band from 600 to 4,000 cycles is not particularly difficult. At the lower frequency, the required diaphragm motion is not large, nor is the sound-chamber clearance particularly critical at the high frequency. The diaphragm of this unit is a moulded reentrant dome of phenolic cloth-base material. Because of its high internal damping, this construction effectively eliminates spurious signals generated by the various higher modes of diaphragm vibration. The sound chamber in front of the diaphragm is of moulded bakelite, chosen for high dimensional stability. Driving the diaphragm is a 2-in. voice coil of copper wire on an impregnated paper bobbin. Dynamic mass of the diaphragm-voice coil assembly is approximately 2 grams.

The magnetic structure for the MF unit includes both ring and slug-type magnets, totalling approximately 27 oz. of Alnico 5 material. Since these magnets must be charged in opposite directions, a high-current surge coil is placed in the space between them; after charging, the leads to the coil are simply cut off, since the coil serves no further purpose. A flux density of 17,500 gauss is attained in the air gap.

The MF channel, handling probably the most important region of the spectrum, has been designed in a conservative, straightforward manner. The bandwidth is not wide, so that response smoothness, high efficiency, and wide angular coverage are achieved throughout this band.

From Table 1 it can be seen that a band of a little over two octaves re-

[2] Patent No. 2,338,262

*(Continued on page 45)*

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# DESIGN DATA for AF AMPLIFIERS — No. 13 Inverse Feedback

**PART 1 — HOW INVERSE FEEDBACK WORKS, AND WHY IT REDUCES DISTORTION OF ALL KINDS AND IMPROVES SPEAKER DAMPING**

INVERSE feedback is the process of applying part of the output of an amplifier stage to the input in such a way as to reduce the total output. Stated another way, it consists of feeding back an amplified signal in phase opposition to the input signal, so as to cause degeneration.

There are many advantages obtained by the use of inverse feedback. Insofar as audio amplifiers are concerned, the most important of these are reduction of distortion and improvement in speaker damping.

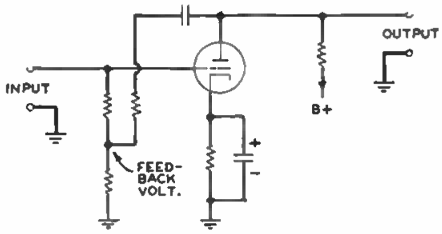


FIG. 1. AMPLIFIER STAGE WITH FEEDBACK

### REDUCING DISTORTION

Inverse feedback operates to reduce distortion generated in all stages around which it is applied. However, correctly-designed voltage-amplifier stages have little inherent distortion. Most harmonic, phase, and amplitude distortion is generated by the output stage and the output transformer. Thus, it is important to include at least these two in the feedback loop, and as many voltage-amplifier stages as possible. The ideal loop includes the whole amplifier, with the exception of those stages which are designed to produce frequency discrimination — such as phono preamplifier stages and equalizers. Volume controls should not be included in the loop, either. This is because it is the nature of inverse feedback to maintain a constant output with a given input, and to maintain a constant frequency response — thus defeating the purpose of volume controls and equalizers.

To understand how inverse feedback reduces distortion, consider it as applied to one stage only. Assume that the amplifier stage of Fig. 1 generates third-harmonic distortion and has a gain of 18. The input signal at Fig. 2A has an amplitude of 1 volt, which should produce the 18-volt inverted solid output waveform at B. However, a third-harmonic component of 5 volts amplitude is generated, indicated by the dashed lines at B. The resultant waveform is shown at Fig. 2C.

Now, suppose the input is increased to 10 volts and that ½ the output waveform, consisting of 9 volts signal and 2.5 volts distortion component, is fed back to the input. The signal component fed back, subtracted from the input signal (since it is of opposite polarity), reduces the input signal to only 1 volt. Effectively, the gain has been reduced to 1.8, and it is easier to consider the operation this way. Thus, with a 10-volt input, there will still be only 18 volts output.

It will be recalled that a 2.5-volt distortion component was fed back also. Fig. 2D shows this as a dashed line, with the 10-volt input signal as a solid line. The stage gain is now only 1.8. The output at E is then an 18-volt signal plus a 4.5-volt distortion component of opposite polarity to the 5-volt distortion component that caused it. Therefore, only .5 volts third-harmonic distortion remains, Fig. 2F. With 20 db inverse feedback (a reduction in effective voltage gain of 10 times) distortion is reduced to about 1/10 its former value, but an input signal 10 times as large is required.

This process can be considered one of dilution. Rather than mix 18 parts signal with 5 parts distortion, 180 parts signal are used with 5 parts distortion. By feedback, the mixture is condensed to 1/10 its size, providing the same output as the former mixture with 1/10 the distortion content.

### SPEAKER DAMPING

It has been stated in previous Design Data Sheets that a speaker shock-excited by program transients acts as a generator because of oscillatory motion at its mechanically-resonant frequencies. This anomalous motion of the voice-coil in its magnetic field causes current to flow in the coil, with a resulting voltage across the coil and the output transformer. With inverse feedback taken from the transformer, a large part of this voltage is fed back to the amplifier input, causing an opposing voltage across the voice coil and severely limiting the free cone excursion. Speaker damping is thereby improved, for any cone motion not following the input signal exactly produces a voltage which opposes the motion.

This discussion is intended only as an aid to understanding the actual operation of inverse feedback. Mathematics have been avoided purposely. There are innumerable texts available with full mathematical treatments of the subject. However, this presentation is basically sound, perhaps easier to understand, and will serve as a background for a more formal study if such is desired.

Part 2 of this Design Data Sheet will give typical circuits and practical limitations of inverse feedback.

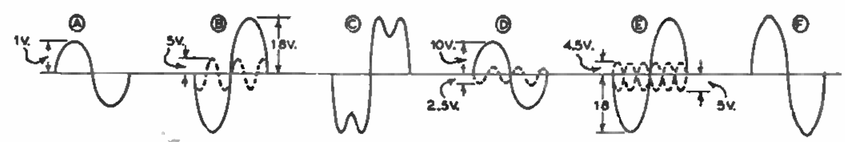


FIG. 2. INVERSE FEEDBACK REDUCES NOT ONLY HARMONIC BUT ALL TYPES OF DISTORTION

## LOUDSPEAKER

*(Continued from page 42)*

mains above 4,000 cycles for reproduction by the HF element. Careful consideration of the design limitations verifies the advisability of this small bandwidth.

**The HF Horn:**

At 4,000 cycles the wavelength is approximately 3½ inches. As stated before, the horn mouth should have a diameter not less than about 1/3 wavelength, or in this case 1¼ inches. Therefore, a mouth diameter of 1½ inches was chosen. For the same reasons as described above, one of the hypex contours was employed. The horn is cast integrally with a supporting cross-member, which attaches to the flange of the LF speaker mounting.

The diaphragm of the HF driver unit is also of moulded cloth-base phenolic material, in a simple dome shape. The driving voice coil is of aluminum wire on an impregnated paper bobbin. This assembly has been designed for minimum dynamic mass, so as to achieve maximum frequency range. The dynamic mass has been held to 130 milligrams.

A dimension extremely important for efficient reproduction at frequencies approaching 20,000 cycles is the clearance between the diaphragm and the sound chamber. Therefore, unusual care has been taken in the design of these parts. Also, careful control is exercised in production to maintain the close dimensional tolerances required. Moulded bakelite is employed for the sound chamber.

The ring-type magnetic structure is of Alnico 5 material, and weighs approximately 7 ounces. The flux density developed in the air gap is about 15,500 gauss.

This HF assembly is quite small, Fig. 1, and presents very little obstruction when supported in front of the LF diaphragm. Another advantage of restricting the bandwidth in the HF channel, and thereby reducing the horn size, is that the angular coverage is extended. However, the broad angular coverage causes some HF signal to be radiated behind the unit. The signal is reflected from the LF diaphragm and tends to create some HF interference. The effects of this have been reduced markedly by moving the HF unit above center. Thus, concentration of this effect in any small frequency range is prevented.

**Design of the Woofer:**

Returning to Table 1, it is seen that the low-frequency channel, including all frequencies below 600 cycles, covers about 5 octaves. This is not difficult to repro-

*(Concluded on page 46)*

## LOUDSPEAKER

*(Continued from page 45)*

duce efficiently with a direct-radiator loudspeaker. The LF element is similar in construction to conventional 15-in. direct-radiator loudspeakers. The curved diaphragm, of moulded, felted paper, is quite rigid except for the compliant periphery. It should also be noted that wide angular coverage poses no particular problems at frequencies below 600 cycles, since the source becomes increasingly smaller in terms of the wavelength as the frequency decreases.

The LF diaphragm is driven by a 3-in. voice coil of copper wire on a sturdy, impregnated-paper bobbin. Moulded phenolic-impregnated cloth is used for the center suspension. It is quite porous, thus permitting air flow but preventing the entry of dust. A similar porous dust-proofing material is provided at the back of the diaphragm to prevent entry of foreign matter into the MF unit and the LF air gap. Both the center suspension and the diaphragm periphery permit large axial excursions of the LF diaphragm-voice coil assembly without non-linear distortion effects.

The magnetic structure of the LF unit is unusually powerful. A 6½-pound Alnico 5 ring magnet provides a total air-gap energy of 30 million ergs; this high magnetic energy affords excellent efficiency and damping throughout the LF band.

**Dividing Network Design:**

Fig. 3 is a schematic diagram of the dividing network. An analysis of the circuit will show the two network sections to be of the parallel constant-resistance type, providing 6 db per octave attentuation. The low-pass filter sections and the input L-pad are shown. All coils are of the air-core type.

Impedance-matching transformers are furnished on request. These transformers are equipped with a short cable and plug for connection to the network, shown in Fig. 4. Space is provided on the network chassis for these transformers. When no transformer is used, a shorting plug completes the internal circuit connections.

**Listening Tests:**

Careful measurements, as well as extensive listening tests, have confirmed the value of this conservative design approach. Not only does this model reproduce a very wide range of frequencies, but it does so without the shrill highs or muddy base often associated with so-called high-fidelity systems. Exceptional response smoothness and extremely low distortion have been achieved, because of the smaller bandwidth covered by each of the component loudspeakers.

# INDEX OF ADVERTISERS


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## EARS: TIN, GOLD, GOLD-PLATED

THE ever-recurrent discussion about whether or not people want high-fidelity or low-fidelity has flared anew. Throwing fat in the fire this time was Richard Weil, Jr., of R. H. Macy's top echelon. Among those burned was Mark T. McKee, Jr., manager of WMLN (FM) in Mount Clemens, Mich. Says he:

"A highly respected magazine has printed some misleading information that demands an answer from a pen more recognized and with more background than my own. On page 99-100 of the June 1951 *Fortune* magazine is an article by Richard Weil, Jr., head of R. H. Macy & Co. Among other things, Weil insists that 'extensive research' among a cross section of listeners — men and women, young and old, well educated and not, trained musicians and FM set owners, has shown that 'the higher the fidelity, the fewer people liked it!' In effect Mr. Weil is saying either that people do not like to attend live concerts (true high fidelity would bring them to the concert) or he is admitting that he does not know what high fidelity is. The object of his whole argument seems to be an effort to prove that listeners do not want high fidelity and therefore manufacturers are justified in charging high prices for radio-phonos incapable of reproducing 'natural' music.

"Please get a copy of the article and read it, then prepare a proper rejoinder."

We would be delighted to prepare a rejoinder . . . and there is much to be said. However, we feel it would be much more effective—and interesting—if our *readers* prepared the rejoinder. So, give us your thoughts and experiences. We'll publish as many of the replies as we possibly can.

Incidentally, the discussion in *Fortune* was provoked by an article in its April issue, written by Bernard De Voto. De Voto discussed many aspects of American business, among them "the curious distributional malfunctioning that has permitted the development of a small industry wholly within the confines of a big one—the manufacture of high-fidelity radio-phonograph combinations. Using only parts that the big manufacturers make, the small one produces for about $175 a machine that outperforms anything the big one puts on the market. He cannot make a machine to sell for $50 as the big manufacturer does, but at $175, which is the bottom of the medium-price range, his product outperforms the big manufacturer's $1,500 machine . . ." This is the item which Weil chose to answer at length.

Now, let's have *your* answer to Weil!