FM-TV

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CONTENTS

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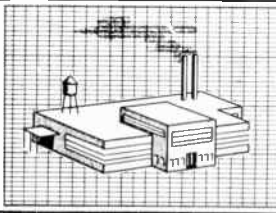
CPA AUDIT

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



Set Production

THIS month, we start to show AM, TV, and FM set production for 1950 against the background of the three preceding years. Supplementing the monthly blocks are dotted lines which show the monthly averages for each year. The latter deserve careful study for, observed against the month-to-month record, they indicate the future trends.

In all three categories, January production exceeded December. This might have been expected of FM and TV, but AM volume, surprisingly, exceeded January '49. However, the RMA data on sets produced last year indicates that the bottom has pretty well dropped out of the AM market.

This is indicated by the fact that 1,025,488 AM table models, or 39 % of the AM table models produced, were billed at less than $12.50. Even more striking are the figures on AM and FM-AM consoles and phono combinations:

	AM	FM-AM
CONSOLES	4,286	13,271
COMBINATION CONSOLES	84,722	369,270
TOTAL	89,008	382,541

Adding up all home-type AM sets, including 55,003 battery models, the total is the astonishingly low figure of 2,924,431. This did not equal the 3,466,940 portable and auto sets, which amounted to 1,175,056 and 2,291,884, respectively. In other words, only 46 per cent of all AM sets were for home use!

If, as the National Television Dealers Association claims, manufacturers have been forcing AM sets by tie-in sales, it is probably in anticipation of reduced production this year.

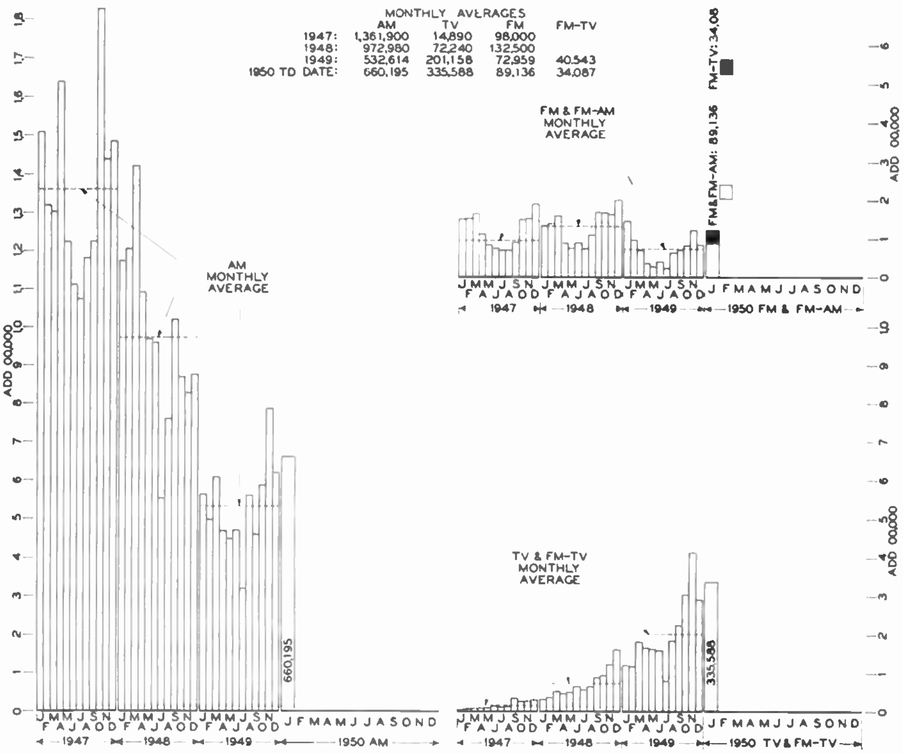
TV models followed a familiar pattern:

TABLE MODELS	1,442,494
CONSOLES	795,982
PHONO MODELS	175,421
TOTAL	2,413,897

In other words, TV sets nearly equalled the number of home-type AM receivers. About 500,000 TV sets were equipped for FM tuning.

Picture-tube shipments to set manufacturers in January totaled 436,252, valued at $11,454,186, up slightly over December. It is most significant to observe that more than 90 per cent of these tubes were of sizes 12 ins. and larger, and 39 per cent were 14 ins. and larger.

Receiver tubes were slightly below December, with 17,649,387 for new sets, 3,897,903 replacements, 628,726 exported, and 96,008 for Government agencies.



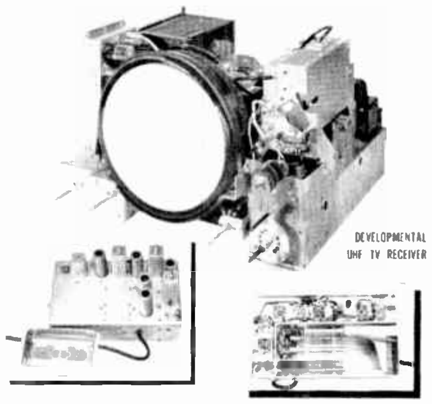
TV, FM, and AM Set Production Barometer, prepared from RMA figures

THIS MONTH'S COVER

This is probably the first published picture of RCA's experimental TV receivers now being used in conjunction with the UHF transmitter at Bridgeport, Conn.

Detail views are shown of the tuning unit, which is mounted on its side at the right of the picture tube.

Conflicting reports are heard about UHF performance in the Bridgeport area, but it is much too soon to draw any conclusions. Three papers will be given at the NAB convention by NBC and RCA engineers, reporting results already obtained.



10th Year of Service to Management and Engineering

SPOT NEWS NOTES

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

FCC Reorganization:

Effective April 3, the following new offices have been created: Office of General Counsel, with Benedict P. Cottone in charge; Office of Chief Accountant, William J. Norfleat in charge; Office of Chief Engineer, Curtis B. Plummer in charge, with John A. Willoughby as Assistant Chief Engineer; and Common Carrier Bureau, with Harold J. Cohen in charge. It is expected that three additional Bureaus will be established later for broadcasting, safety and special services, and field engineering and monitoring. FCC announcement explained that these new Bureaus will be "responsible to and subject only to the Commissioners."

Condenser Paper:

Major realignment of their paper production is indicated in the purchase of the Smith Paper Company, Lee, Mass., by Peter J. Schweitzer, Inc. at a price of $10,000,000. Research facilities will be pooled in a new department under direction of secretary-treasurer Peter Schweitzer. George Mintz, formerly in charge of the Schweitzer plant at Elizabeth, N. J., has been named general manager of the Smith Division.

No More Worn Transcriptions:

Here's an important extra use for tape recorders. At an increasing number of stations, new transcriptions are recorded immediately on tape. This not only eliminates wear and scratches on the discs, but enables producers to tape and edit complete shows in advance.

CBS Color Set Problem:

Testifying at the FCC color hearing, Dr. Peter Goldmark said that CBS is not afraid to compete in a double standard situation if the RMA would promise to make CBS sets. He was probably thinking of the narrow escape of FM at the hands of indifferent manufacturers and broadcasters.

Curtis B. Plummer:

Appointed Chief Engineer of the FCC. He was born at Boston in 1912, was graduated with a B.S. degree from the

(Continued on page 7)

Professional Directory

SPOT NEWS NOTES

(Continued from page 6)

University of Maine in 1935, joined the Commission in 1940 as radio inspector in Boston, and was advanced in 1946 to the position of Chief of the Television Broadcasting Section.

New UHF Tetrode:

Eitel-McCullough has announced a new 4X150G tetrode for use as an oscillator or amplifier up to 1,000 mc. Output is 50 watts at 1,000 mc., up to 100 watts at 750 mc.

New Campus FM Station:

Northwestern University, Evanston, Ill., is installing the first 10-watt FM broadcast station in the Chicago area. Already, 124 students have applied for staff positions. William Butler, instructor in radio announcing, will be station manager. Speech School faculty members will serve as a board of directors. Call letters are WNUR.

Dr. Antonio R. Rodriguez:

Now head of the ceramics laboratory at Electrical Reactance Corporation, Franklinville, N. Y. Previously, he was in charge of ceramics research for Zenith.

FM Signal Generator:

Boonton Radio's new model 202-D is designed for use with telemetering receivers and associated applications. Range is 175 to 250 mc., with continuously adjustable deviation ranges of 0-24, 0-80, and 0-240 kc. Internal audio oscillator has 8 fixed frequencies between 50 cycles and 15 kc.

Rectangular Tubes:

There seems to be a definite shift to the use of rectangular picture tubes for new TV receiver models brought out since the first of February. Basis of this observation is the literature we have received from manufacturers.

Anti-Transitcast Battle:

Suspicion grows that the financial support of the legal battle against transitcasting in the District of Columbia is not coming from private citizens, but from the *Washington Post*.

Capacitor Plant:

Is being set up at Deuville, N. J. by Centralab for added production of ceramic capacitors. About 300 people will be employed, with Henry Horn, from Milwaukee headquarters, in charge.

Joshua Seiger:

Elected vice president in charge of engineering at Freed Radio Corporation.

(Continued on page 8)

Professional Directory

SPOT NEWS NOTES

(Continued from page 7)

He joined Freed as director of research and development in 1948, soon after coming to this country from England.

RF Waveform Monitor:

Rack-mounted unit announced by Du Mont Laboratories monitors unrectified signal at the RF transmission line. Cathode-ray tube displays RF carrier voltage on a linear time base at field or line frequency. The relative amplitude of various portions of the RF envelope can be measured to accuracy prescribed by FCC. Also, any modulation level can be read as percentage of peak signal.

National FM Week:

NAB Convention will consider a plan to bring together all manufacturers and broadcasters interested in FM, to stage an intensive promotion this summer.

Harry Seelen:

Appointed chief engineer of RCA's tube plant at Lancaster, Pa. He succeeds Dr. Dayton Ulrey who retired recently, but continues as a consultant.

One-Year Tube Guarantee:

Sylvania has announced that it will replace its picture tubes without charge in case of failure due to defective workmanship within a year from the date stamped on each tube at the time of sale. This applies to tubes sold to set manufacturers, or through dealers. To obtain replacement, the defective tube must be returned to the factory.

Memo to Movie Producers:

From Zenith president McDonald: "Television receivers are today selling at the fabulous rate of over 100,000 per week, which means that in each week over 400,000 more people are going to the movies less and less. Some are stopping altogether. Phonevision will change television from a menacing competitor to a profitable partner."

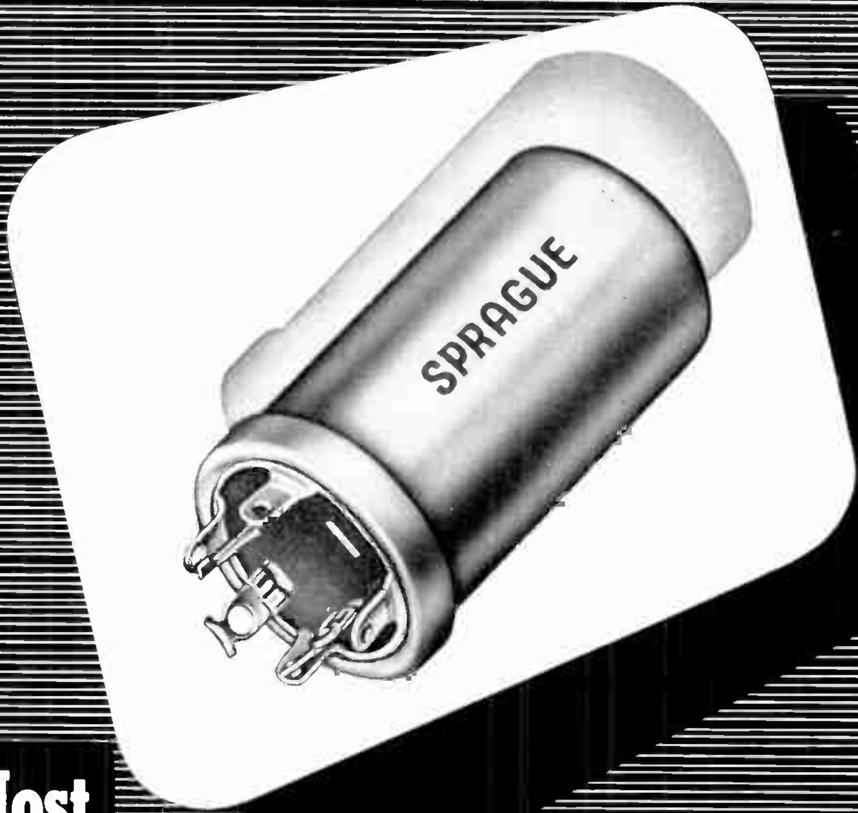
Miniature Plug-in Relays:

New hermetically-sealed SM series plugs into miniature 7-pin socket. Retaining spring permits mounting in any position. SPDT springs pull in at 3 milliamperes, 75 milliwatts. DC windings available from .155 to 8,000 ohms, with power ratings up to 1.75 watts. Also furnished without cover, for single screw mounting. Described in bulletin 102, Potter & Brumfield, Princeton, Ind.

More FM for N. Y. City:

Over $330,000 will be spent for new stations just authorized by the FCC. These

(Concluded on page 33)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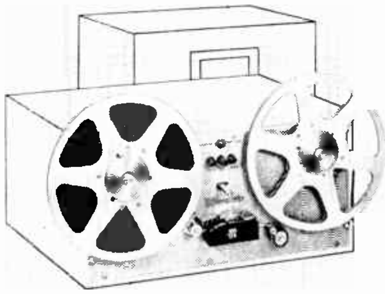
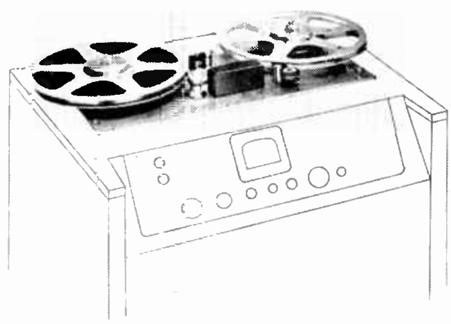
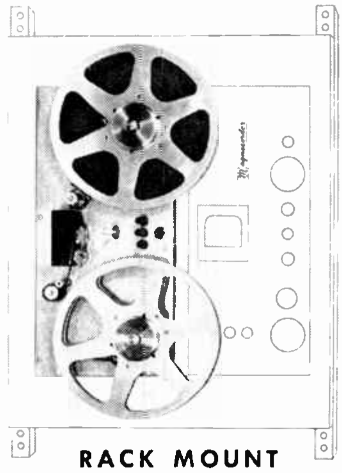


PORTABLE



CONSOLE



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REPORT ON COLOR TELEVISION

WHAT HAPPENED AT THE FINAL FCC TESTS—PRESENT STATUS OF COLOR TV—PROBABLE COURSE OF ACTION BY THE COMMISSION—*By* MILTON B. SLEEPER

THE final comparative tests of color television, held for the FCC on February 23 in their laboratory at Laurel, Md., was probably the most dramatic show staged by radio engineers since Marconi's reception of transatlantic signals in 1901. That is not intended to imply that the color tests were the most important event during that period of radio history. It remains to be proved that color can become important public service. But in the extravagant expenditure of engineering blood, sweat, and tears, poured out under the pressure of keen competition, this occasion unquestionably deserves top billing.

We left Washington in time to drive the twenty miles and arrived at the Laurel Laboratory nearly an hour before nine o'clock when the tests were scheduled to start. The brick building contained a single, high-ceilinged room, with a small mezzanine floor. Although admission was limited strictly to ticket-holders, and the number of tickets was limited to about one hundred, we were early enough to walk in unchallenged.

Early as we were, twenty-odd engineers were making last-minute checks on as many television receivers. On the ground floor, there were two rows of sets, back to back, and another row on the balcony, installed by Columbia Broadcasting System, RCA, and Color Television, Inc. The big room was quiet. Groups of two or three men talked in whispers as they moved from set to set, looking at the images and touching up the controls. The sound channels were cut off. An eerie touch was given to the proceedings by the continuous movement of the test-pattern images. This was to prevent burning the camera tubes. CTI used projection models. RCA had 10-in. and 16-in. direct-view types, and projection models, also. CBS had direct-view sets, some with plain 10-in. tubes, others with magnifiers to give a 12-in. effect, and one with a 12-in. tube and magnifier giving a 16-in. picture. Black-and-white sets were added for purposes of comparison.

Shortly before nine o'clock, the room filled rapidly, and soon it was so crowded that it was difficult to move around. There was just space for two rows of folding chairs between the sets and the walls. Late-comers filled the corners and every vantage point. At the last minute, Harry Plotkin, the FCC's Assistant General Counsel, began to count out seats in our row, right up to us, and asked the occupants to let the Commissioners have those chairs.

Commissioner Robert Jones took the place next to us, and we had the pleasure of meeting him for the first time. Axel Jensen, of Bell Laboratories, sat on our right. Chairman Wayne Coy appeared, nervously alert, seeing everything without seeming to move his eyes; Miss Frieda Hennock, about whose charming manner and appearance there was nothing to suggest her legal background or her newly-acquired experiences with the radio industry; Paul Walker, the Commission's expert on common-carrier matters; George Sterling, FCC career man and former Chief Engineer; and Edward Webster, Coast Guard Commodore and communications specialist. Rosel Hyde was absent, since he was in Cuba at the NARBA Conference.

Also in our part of the room were Allen Du Mont and Tom Goldsmith, David Sarnoff and C. B. Jolliffe, Frank Stanton and Peter Goldmark, Don Lippincott and George Sleeper, Senator Edwin Johnson, George Beers, William Lodge, and Elmer Engstrom. George Gillingham, FCC Director of Information, told us that no list was made of those present, but the attendance certainly represented the upper bracket of industry management and engineering.

Just before the demonstration started, each one was given a timetable of the tests, and a brief description of the methods and purposes. FCC engineers made the official observations, to be read later into the record of the television hearing. With the tests under way, the atmosphere of tension relaxed gradually. The engineers saw that their charges were performing creditably, and their attitude of apprehension gave way to confidence that their work had been well done. So it proved to be. However, as if to make the occasion authentic, a transformer in one of the CTI sets went wrong, filling the air with the acrid smell of burning insulation.

The accuracy of color values on the RCA and CBS images, and the amount of detail was far beyond anything we had expected to see. In fact, we liked the color in the television images more than color in motion pictures.

Particularly noticeable was the absence of flicker, as well as the untrue colors so often seen in colored motion pictures. CBS and RCA images were not only excellent in color value, detail, and agreeable viewing quality, but they left little to require improvement. As for black-and-white, it seemed dull indeed by comparison! As CTI had announced, they were not prepared to give a finished demonstration.

With barely enough room to move between the front row of seats and the lineup of receivers, the FCC engineers and others who were comparing the images on the competing models had to squat down on their heels and shuffle back and forth. As the tests proceeded, they were heard to complain that their knees were acquiring a permanent set, and that they mightn't be able to stand erect when the hearing is resumed! During one of the brief intermissions, Miss Hennock graciously caused containers of coffee to appear from whence we do not know.

The foregoing is offered to sketch in the scene and the setup of the final comparative tests which will be described here in detail.

1: TEST METHODS HOW THE 11 COLOR TESTS WERE MADE

The final comparative color tests were set up on a timetable basis. During tests No. 1 through 6, WOIC transmitted signals for CBS on channel 9, WNBW for RCA on channel 4, and WMAL-TV for CTI on channel 7. Although the programs originated at separate studios, the stations transmitted similar material during each test. Monochrome receivers were set up for checking black-and-white reception. The signal strength at each receiver input was 1 millivolt. All the sets were operated simultaneously.

TEST No. 1: A wedge test-pattern, with one-half the wedges in color, was transmitted for five minutes, and the pattern was moved slowly from side to side, to protect the camera tubes; then for five minutes the pattern was moved horizontally and vertically somewhat faster, to simulate usual camera movements.

TEST No. 2: A double paddle was rotated at ½, 1½, 5, and 15 RPM for five minutes; then a single paddle at the same speeds for five minutes. The purpose was to bring out any tendency for the colors to break up during rapid motion.

TEST No. 3: A keyboard test-pattern was shown for five minutes, first in the normal position, and then rotated slowly until the maximum width of the keys was vertical.

TEST No. 4: A special test pattern of fairly fine lines was shown for five minutes.

TEST No. 5: Staple products including boxes of soap, packages of cigarettes, canned goods, and toweling, all in multicolor designs, were shown for five minutes.

TEST No. 6: Conventional live-talent programs were transmitted for fifteen minutes. The time was divided between singers, dancers, and models, with full-length and medium shots, and closeups. All colors were represented in the costumes and backgrounds.

TEST No. 7: Five minutes of program material was transmitted at present standards to show standard monochrome on the color receivers. All sets during this test were operated from channel 4 signals supplied by the Laboratory, but originating from WNBW.

TEST No. 8: During test No. 8 through 11, the sets were operated sequentially on channel 4. Interfering signals were supplied by the Laboratory. The program material was similar to that used in test No. 5. Over a period of fifteen minutes, co-channel interference, offset by 10.5 kc., was transmitted at -23 db, and then interference from a normal-tolerance co-channel signal at -34 db. The interference was from a standard monochrome signal.

TEST No. 9: Proceeding slowly from the low-frequency end of the channel, up through the audio carrier, and back again, interference was transmitted from other in-channel signals at -20 db, the ratio of the peak of the sine wave interfering signal to the peak of the TV signal. This test occupied fifteen minutes.

TEST No. 10: This was a test of fringe-area reception. The signal to each distribution amplifier was reduced to 100 microvolts across 50 ohms.

TEST No. 11: The final test was to check the effect of ghosts. A ghost signal of varying phase, at -12 db, was applied to each receiver.

Official observations made by the FCC engineers are available in the testimony of the television hearing. No specific comment, therefore, will be made here. Generally, the RCA and CBS sets seemed closely comparable in performance. No serious defects were disclosed, as far as we could see, in either system. Unfortunately, we sat directly in front of an RCA projection set. Its performance was not equal to that of RCA's direct-view models as to color values. They were dim, lacking the brilliance and clarity of the direct-view images. Therefore, to make a proper comparison with CBS reception, we had to move down the line of sets to take a brief look at one of the direct-view RCA models. Only when the tests were completed, and regular studio program material was being transmitted, were we able to stand where we could see direct images of both types simultaneously.

2: CBS COLOR PERFORMANCE AND LIMITATIONS OF THE SYSTEM

If movies are to be used as a basis for rating the performance of color television systems, it seems to this observer that the quality of color reception demonstrated by CBS on February 23 might be considered by the general public as certainly equal, if not superior, to the best color movies.

The color values of flowers, familiar trademarks, packages, and closeups of performers' features were truly excellent. And they were definitely easier to watch than motion pictures. This was due to the agreeable quality of the colors, and to the absence of flicker. While time might not confirm this first impression, it seemed that it would be more entertaining to watch a poor TV show in color than a good show in black-and-white.

Reception at the FCC trials was so perfect, and so lacking in the various imperfections that characterize home-set performance as to create the feeling that the image quality was due to the establishment of ideal conditions. Perhaps the same results could be obtained in the average home, but it is only reasonable to expect that color would suffer the same deterioration as we have observed at many black-and-white installations. We would expect viewers to prefer average black-and-white reception to color that is anything less than perfect.

There is no doubt but what the CBS color-wheel system offers important advantages, at least at this time, in the matter of cost to both broadcasters and viewers. Present camera equipment can be adapted to the CBS color system at reasonable expense. And no basic changes are required in receiver designs, except to permit operation on 405 lines instead of 525. In that connection, it should be pointed out that loss of resolution due to the reduced number of lines was evident during transmission of the test patterns, but it is doubtful that viewers could recognize the difference during regular program transmission.

It is not true, however, that color performance as demonstrated by CBS can be duplicated by putting a color wheel in front of a standard black-and-white receiver operated with a 405-line adapter! The reason is that the color wheel causes up to 90% loss of light. To make up for this loss, the voltage on the picture tube must be increased greatly, and this calls for substantial revisions in the receiver.

The much-publicized story of the amateur who made a disc of cellophane and was thereby able to get CBS color transmission may be true enough, but any resemblance between the images he was able to see and those produced by CBS at the FCC tests would be purely coincidental. It is a bright idea, but an over-simplification.

One important improvement incorporated in the CBS receiver was the use of automatic synchronization of the color wheel.

With this addition, the system has been brought to its ultimate peak of performance. Unfortunately, despite the advantages of immediacy that it offers, the impression prevails that it is as unsuited to establishment as a permanent standard as the whirling disc first used for television scanning. As in the case of direct-current power transmission, it has proved that a useful service can be performed, but it must give way eventually to a more versatile means, comparable to alternating current in the field of power distribution.

3: RCA COLOR PERFORMANCE AND LIMITATIONS OF THE SYSTEM

Whatever the failings of RCA color television at previous demonstrations, the performance was little short of perfect on February 23. Looking at one receiver that must have had 16-in. tubes, we were amazed to see that the color dots showed up as distinctly as an enlargement of half-tone color printing. Comparing a CBS receiver with an RCA model right beside it, there was no perceptible difference in the color values of similar program material. The three tubes of the RCA set registered perfectly, and we marveled that such precision was physically possible. Also, we noticed that, once the demonstration started, no further adjustments of the controls were made, and we thought that the achievement of such precision control of three cathode-ray tubes should be added to Dr. Jolliffe's list of the marvels of the radio art.

Then, in a more practical vein, we wondered by what factor such receivers would multiply the problems of maintenance if they were offered to the public. Even before that would come the job of matching both camera tubes and picture tubes. They can't be taken off the shelf and inserted in television cameras and receivers. Tube manufacture has not reached that state of precision.

Even in the sets demonstrated there was one serious mechanical fault. Because the faces of the tubes are arranged on three sides of a square, the tube facing the viewer is set far back in the cabinet. Therefore, it is necessary to stand directly in front of the opening in order to see the entire image. At a distance of 6 ft., the complete screen can only be seen by two people. This fault will be overcome, presumably, by the single color tube that RCA now has under development.

The cost of studio equipment and of the receivers is certainly much greater than the CBS units. If every set in use today were equipped for color, it is doubtful if many broadcast stations could afford the investment in RCA color equipment. And there is the cost of producing any amount of program material in color for either system. It could be done with live shows, but what about the very large number that are transmitted from film? How many sponsors would be willing and able to stand the increased cost? Also, RCA color can't be networked on coaxial cable.

On the other hand, there is the matter of public preference. If viewers could have the quality of color reception demonstrated at the FCC tests, would they be willing to look at any black-and-white reception? The introduction of the former might kill all interest in the latter, and thereby show a net loss to the broadcasters.

4: FCC TIMETABLE SCHEDULE FOR ENDING THE TV FREEZE

Now all the color demonstrations have been concluded, but the Commission is still far from answering the two questions of prime importance to the radio industry: When will the freeze be lifted? Will commercial color television broadcasting be authorized?

At this moment, it is only certain that the Commission will not accede to demands that the VHF freeze be removed in the immediate future.

As to the other points at issue, no one can predict with assurance what the FCC will decide, or when, but the facts involved furnish a fairly definite picture of the probabilities. The following presents the consensus of well-informed opinion:

1. Both the CBS and RCA color television systems will be given the green light for commercial operation.

2. The engineering standards for color will be flexible enough to permit the use of any other 6-mc. system on demonstration that it is ready for the public. This will permit CTI, the third of the present color proponents, to qualify when it has proved out its equipment.

3. The FCC will not lift the freeze, in whole or in part until the issues of color, and standards and allocations for both VHF and UHF have been decided.

The FCC has devoted too many months of the industry's time and too much of the taxpayers' money to color hearings to decide against color now.

And the Commission must realize that a decision against color would kill that service for five or ten years. CBS and RCA would accept an adverse decision by the FCC as a stop signal. As they did after the 1947 denial of color, they would shut up their color television laboratories, take their tax losses, and devote their resources to building their positions in monochrome television. The FCC can hardly afford to face the charge that it killed color.

On the other hand, an FCC decision to recognize color could hurt the industry. No one can be sure that the commercialization of color will not burden the industry with a multi-colored baby elephant. The cost of raising it from infancy may be more than the industry can afford. But no one will be able to prove the FCC in error, even if that should prove to be the case.

Some 200 parties are waiting to be heard on requests for changes in the proposed VHF-UHF allocation table.[1] Meanwhile, the FCC is convinced that it cannot afford to rush into the allocations phase of the hearing without knowing more about possible color television interference. It is not going to be goaded into an error by acting on incomplete information.

There is considerable lack of understanding as to the steps involved in the television hearing which must be completed before the freeze can be lifted. The considerations with which the Commission must deal are not merely technical, but are concerned with national policy, not untinged by political pressure. And it must be remembered that the FCC must prepare to make its decisions stick in any subsequent legal actions which may be brought by dissatisfied individuals or organizations.

Assuming that the hearing proceeds without serious delays that cannot be anticipated now, an approximate timetable can be made up in this way:

APRIL 15: Evidence completed on color. Hearing started on the Bell Telephone petition for allocating the band from 470 to 500 mc. to multi-channel common carrier communications.[2]

MAY 1: Hearing started on thirty general comments concerning engineering matters and allocations principles.

JUNE 1: Hearing started on proposal to reserve channels for non-commercial, educational television stations.

JUNE 10: Hearing started on two hundred comments concerning proposed allocations to specific communities.

SEPT. 1: Tentative decisions announced on all issues, including color and new rules, standards, and allocations for VHF and UHF television.

OCT. 1: Oral argument before the Commission *en banc*.

NOV. 15: Final decision issued on all issues, and an announcement of the lifting of the freeze.

JAN. 1: Processing of applications for new television stations started, and first hearings scheduled on conflicting applications.

The foregoing is a realistic appraisal of the time required for the steps which must be completed before television is freed from the restrictions that have been in effect since September 1948. This timetable can be met if no unforseen delays arise, but there is no likelihood that the lifting of the freeze will be announced before November 15.

[1] The proposed VHF and UHF allocations table, showing the frequencies assigned to each city as well as the cities assigned to each frequency, was published in *FM-TV*, August, 1949. Copies are still available.

[2] In the allocations table effective July 1, 1949, the band from 470 to 475 mc. was labeled "facsimile broadcasting," and 475 to 500 mc., merely "broadcasting." The complete table for 25 to 30,000 mc. was published in *FM-TV* for June, 1949. Copies are still available.

BETTER QUALITY FROM REMOTES

THE MANY USES FOR A MOBILE PICKUP TRANSMITTER MAKE IT A HIGHLY PROFITABLE INVESTMENT FOR BROADCAST STATIONS — *By* FRANK A. GUNTHER*

THE use of wire lines to carry programs originating outside the broadcast studio always involves extra work, worry, and expense. If no lines are available, as is frequently the case at outdoor events, there can be no pickup — unless a mobile FM pickup transmitter is available. In that case, the remote offers no problem, for the transmitter can be driven to the scene, along with the microphones and amplifiers, and a high-quality link established with the studio or the station in short order.

Many Different Uses:

As an investment, a mobile pickup transmitter pays off through substantial savings in man-hours and line charges, extra income, and unusual special-events service to listeners. Added to this is the superior program quality afforded by an FM pickup transmitter, as compared to most of the lines that must be used for remotes.

Experience with such a mobile unit shows that it is a very busy item of equipment, all year round. For example, if a series of events is to take place at a public auditorium or sports center, an antenna can be installed and left in place. Then the truck can be driven to a convenient spot, and the transmitter connected in a few minutes. The work and expense involved is much less than when wire lines are used.

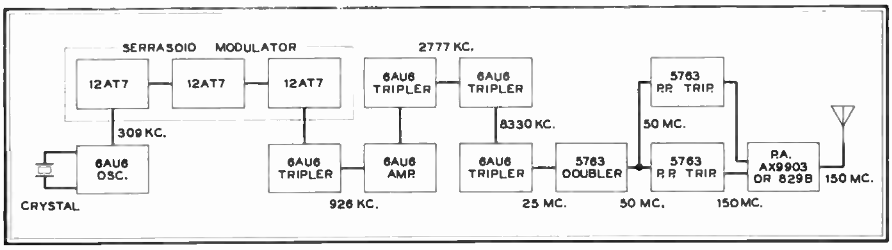


Fig. 1. Block diagram of the REL 695 pickup transmitter for 152.87 to 170.15 mc.

The mobile transmitter can be used as a relay for feeding programs that are beyond pickup range at the station, provided the truck can be sent to high ground at an intermediate location. Again, a permanent antenna for such relay use may be warranted.

If the studio-transmitter line or radio link fails, the mobile transmitter is a most valuable piece of emergency equipment. Such use is authorized by the FCC, in cases of "damage or impairment of the regular circuits."

In Alaska, Hawaii, and Puerto Rico, FCC Rules allow the use of pickup transmitters "for any auxiliary purpose including inter-city relay circuits."

Broadcasters who own mobile pickup transmitters find that their use is only limited by the ingenuity of their program directors and engineers, for there is a wide scope of applications.

FCC Requirements:

FCC Rules governing experimental and auxiliary broadcast services, Amendment No. 397, effective September 10, 1946, provided 11 channels between 152.87 and 170.15 for mobile pickup transmitters. These were continued in the allocations effective July 1, 1949.[1] The first nine frequencies listed below are subject to the restriction that they must not cause harmful interference with industrial radio services, while the last two are subject to special restrictions in northeast USA:

152.87 mc.	153.11 mc.	153.35 mc.
152.93	153.17	166.25
152.99	153.23	170.15
153.05	153.29	

An FM transmitter operating on one of these channels with a deviation at 100 per cent modulation of plus and minus 22.5 kc. is well within the limits of the 60-kc. channel width. Allowable frequency tolerance is .005 per cent.

Nineteen 20-kc. channels between 26.10 and 26.48 mc.[1] are available for use as cueing circuits in conjunction with mobile pickup operation.

Finally, a mobile pickup transmitter, if its design conforms with FCC regulations, may be operated by anyone "holding any class of radio operator license or permit."

Data on Equipment:

The REL model 695 mobile pickup equipment illustrated here was designed

*Vice President, Radio Engineering Laboratories, Inc., 36-40 Thirty-Seventh Street, Long Island City 1, N. Y.

[1]The complete allocation table and footnote references were published in *FM-TV*, June, 1949. This table covers all channels from 25 mc. to 30,000 mc. Copies of this issue are still available.

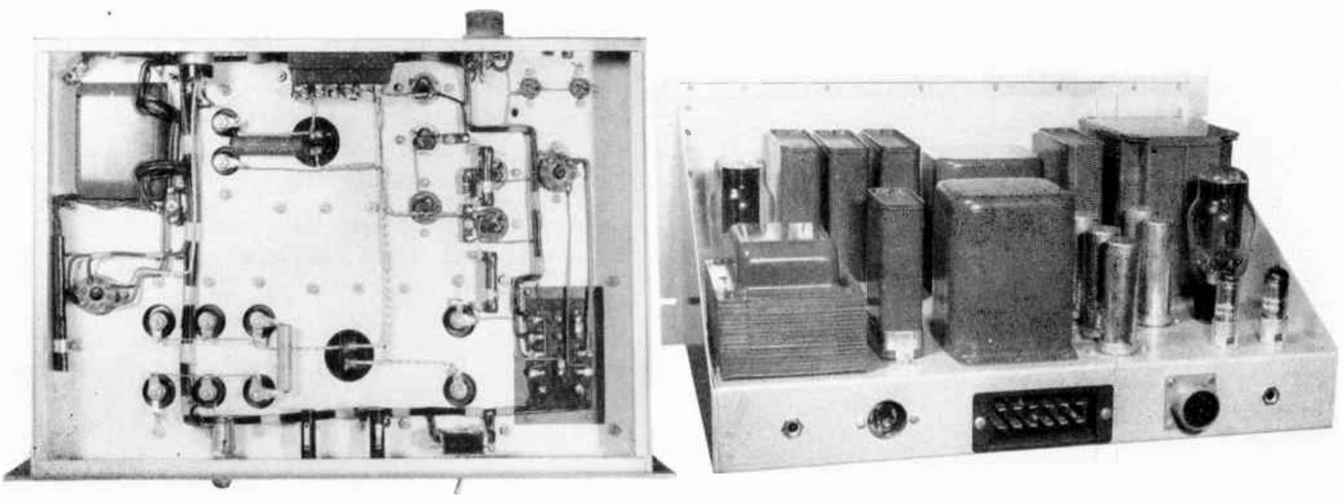
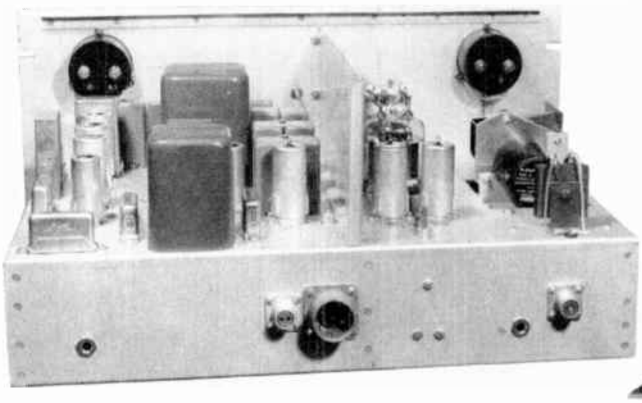


Fig. 2. Bottom and rear views of the AC power supply. Filter section is also used with 12-volt dynamotor, drawing 35 amperes



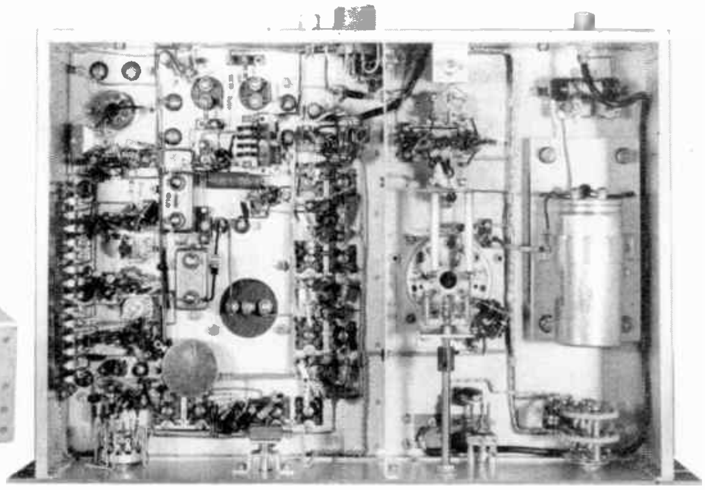


Fig. 3. Rear and bottom views of transmitter section. Output is 50 watts. Note cooling fan at right of chassis

throughout for the requirements of broadcast operation, rather than as a modification of mobile communications gear. As a result, it is suited to continuous operation required, for example, when it is employed as an emergency studio-transmitter link. Also, it should be noted that no modification is required for use at high altitudes. This is important in many areas, because a transmitter may operate for long periods at sea level, but break down at a high level as a result of overheating.

Fig. 1 shows the block diagram of the transmitter, including the Serrasoid modulator. There are detailed views of the power supply in Fig. 2, and of the transmitter in Fig. 3. Separate metal cases permit the units to be carried and set up as in Fig. 4, or mounted on a standard rack. Connecting cables are secured in the cover which snaps on the front of the power supply.

An interesting and important feature of the power supply is that it is designed for operation on 115 volts, 50 to 60 cycles, drawing 350 watts, or with a dynamotor on 12 volts DC at 35 amperes. The shift from AC to a dynamotor unit requires only a quick change in the power-cable connection. Thus, a part of the power supply filter circuit is used for DC. Even the motor for the cooling fan operates interchangeably.

On the transmitter, the only adjustments on the front panel are for the grid, plate, and output coupling of the final amplifier. This meets the requirements for a transmitter operated by a third class radiophone operator.

Characteristics of overall performance show why the program quality is so much better than that of wire lines. Signal-to-noise ratio of the transmitter at 100% modulation is down 60 db, and the audio response is flat within 1 db from 50 to 15,000 cycles. Distortion measured from the transmitter input to the receiver output is less than 1½% RMS at 100% modulation from 50 to 15,000 cycles.

Of course, the equipment can be carried in any type of car to the location where it is to be used. Some broadcasters use a conventional station wagon. Others have more elaborate installations, such as that in the panel truck, Fig. 5. This belongs to WWHG-FM, Hornell, N. Y. To meet some of their special requirements, an engine-driven generator is provided for use at outdoor events where no AC connection is available. The truck also carries a 646-B FM broadcast receiver for relay service, and a low-frequency transmitter-receiver to furnish a cueing circuit.

Antenna Designs:

Ordinarily, 3-element antennas are used for relay transmission and reception. The driven element is a folded dipole, with a director and reflector. A bazooka is furnished to match a 51-ohm, solid-dielectric cable. This antenna has a gain of at least 3 db over a single dipole.

Gain of 10 to 12 db over a single dipole can be obtained from a corner reflector antenna, designed for covering greater distances.

Both types are horizontally polarized. This has the particular advantage of less interference with and from communications systems on the same channels, since

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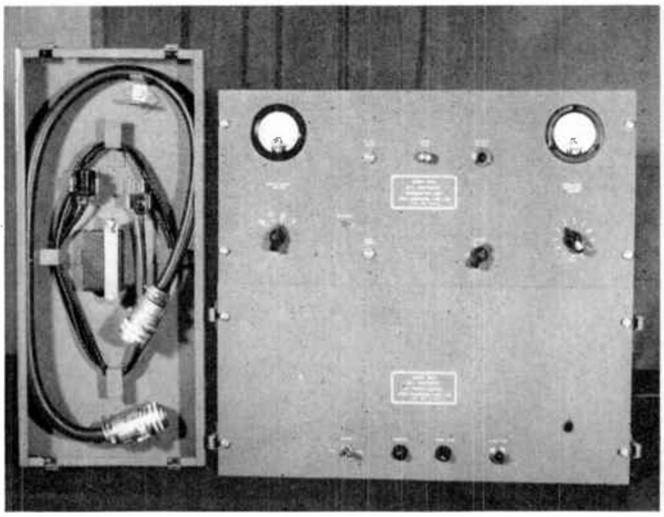


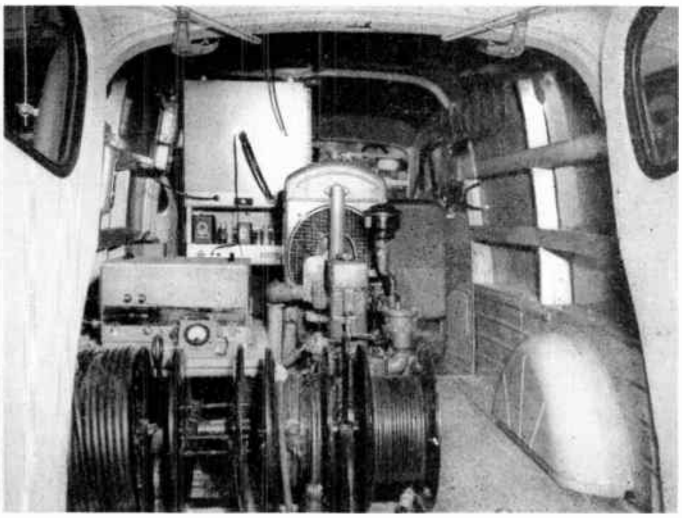


Fig. 4. Front of transmitter and power supply. Cover holds cables. Fig. 5. Rear view of installation in WWHG panel truck

WHAT'S NEW THIS MONTH

THE IRE CONVENTION — SIR WATSON-WATT'S IRRESPONSIBLE PHYSICISTS — COMMISSIONER STERLING COMMENTS ON FM — QUOTES FROM CHAIRMAN COY

THE IRE Convention in New York was tremendously successful, not only as to the quality and scope of the papers, but in the skillful management of the affair, and its enthusiastic support by the membership. A record number of exhibitors at the Grand Central Palace drew attendance which topped last year's figure by a substantial amount.

Some of the members expressed the feeling that the expansion of the Institute of Radio Engineers into non-radio industrial electronics has now been carried to the point where there is need of a society devoted specifically to the interests of those concerned with radio communication.

At any rate, there was ample evidence that the affairs of the Institute have prospered under the administration of Stuart Bailey, the outgoing president, and every reason to expect that in-coming president Raymond Guy will maintain the present rate of progress.

AT a time when the affairs of the radio industry are so entangled in the political-social-economic-scientific aspects of government regulation, it was particularly interesting to hear the observations made by IRE vice president Sir Watson-Watt at the President's luncheon, during the Convention.

He proved to be a very engaging speaker, and the fact that he called forth frequent laughter did not detract from the effectiveness with which he discussed the serious subject of the relations between physicists and politicians.

Describing the genesis of English radar developments in 1935, he referred to his "group of irresponsible physicists who made their own toys to play with propagation." Then he qualified this by referring to the "reasoned irresponsibility" which impelled their work, by way of emphasizing the need of intellectual freedom in the exploration of new fields. His reference to the mistake of making "physicists subject to stultification, frustration, and perversion by politicians" reminded us of the FCC's impatience to set rules and standards, fencing in the growth of television, to the end that sets bought for use in one part of the USA must be operable in any other area, and that the public be protected from obsolescence.

Suppose, for example, our Government had ruled against AC current in order to protect the public against the obsolescence of DC equipment.

Think what would have happened to the industry if the early Federal Radio Commission had ruled against CW transmission on the grounds that it could not be heard on crystal-detector receivers! Is anyone prepared to say that television will not make comparable progress in the next ten years?

NAB ENGINEERING CONFERENCE

Hotel Stevens, Chicago, April 12 to 15

WEDNESDAY, APRIL 12: Registration and Exhibits open, informal reception 6:00 to 8:00 p.m.

THURSDAY, APRIL 13: 9:00 a.m., North Ballroom. Presiding: Jack R. Poppele, WOR
Television interference tests: J. W. Wright, CBS
NBC Bridgport UHF installation: R. F. Guy, NBC
1. One-kw. UHF TV transmitter: T. M. Gluyas, RCA
2. High-gain UHF TV antenna: O. O. Feit, RCA
Five-kw. TV transmitter: John Ruston, DuMont
Synchronizing generator: C. L. Ellis, G.E.
Selecting TV transmitter site: L. E. Rawls, WSM
UHF propagation tests: R. Harmon, KDKA

Luncheon Session: 12:45 p.m., Boulevard Room. Presiding: Neal McNaughton, NAB
Address of welcome: Judge Miller, NAB president
History of Broadcasting: R. F. Guy; IRE president.

Afternoon Session: 2:30 p.m., North Ballroom. Presiding: Oscar C. Hirsch, KFVS
Optical requirements for TV: F. G. Back, Zoomar
Studio lighting: Richard Blount, G.E.
Theatre TV facilities: R. F. Bigwood, DuMont
Movies: Construction of 1,057-ft. tower, I.D.E.
Moderate-size TV installation: E. L. Adams, WHIO
Grid-modulated amplifiers: J. Lorber, Raytheon

FRIDAY, APRIL 14: 9:00 a.m., North Ballroom. Presiding: John H. Dewitt, Jr., WSM
Five-kw. TV transmitters: E. Bradburd, Federal
Supergain TV antenna for VHF: L. J. Wolf, RCA
16-mm. projectors: B. Foulds, F. Gillette, GPL
Bell System TV networks: C. E. Schooley, AT & T
Sound diplexing: Staschover & Miller, Federal
Television economics: Robin D. Compton, WOIC
10-w. FM for education: T. McConnell, Collins

Luncheon Session: 12:30 p.m., Boulevard Room. Presiding: A. James Ebel, WMBD
Television possibilities: G. E. Markham, NAB

Afternoon Session: 2:30 p.m., North Ballroom. Presiding: K. W. Pyle, KFBI
Transit radio: Charles Sheridan, TR Inc.
Miniature condenser mike: J. K. Hilliard, A-L
Facsimile: John V. L. Hogan, Hogan Labs.
One-kw. AM transmitter: L. K. Findley, Collins
Disc cutting technique: W. S. Bachman, Columbia
Five-kw. AM transmitter: F. Grimwood, Gates

SATURDAY, APRIL 15: 9:00 a.m., North Ballroom. Presiding: Neal McNaughton, NAB
Magnetic recording advances: W. E. Stewart, NAB
FCC audio tests: George Adair, Consultant
Engineers & management, R. P. Doherty, NAB
FCC-Industry roundtable: Stuart Bailey, presiding

FCC	INDUSTRY
Curtis Plummer	Raymond Guy, NBC
John Willoughby	E. K. Jett, WMAR
James Barr	E. M. Johnson, MBS
Cyril Braum	William Lodge, CBS
Edward Allen	Frank Marx, ABC
Edward Chapin	

A LETTER received from FCC Commissioner George Sterling covered several points concerning FM receivers, interference, and audience growth. The full text is quoted below:

With regard to the article concerning FM receivers in your January issue, you asked the question "Do communication receivers have something that home sets lack?" Then you proceed to say it is not audio quality, for they are designed to attenuate sharply above speech frequencies; you state that the difference lies in three other factors, namely high sensitivity, effective limiting, and the use of an adequate antenna.

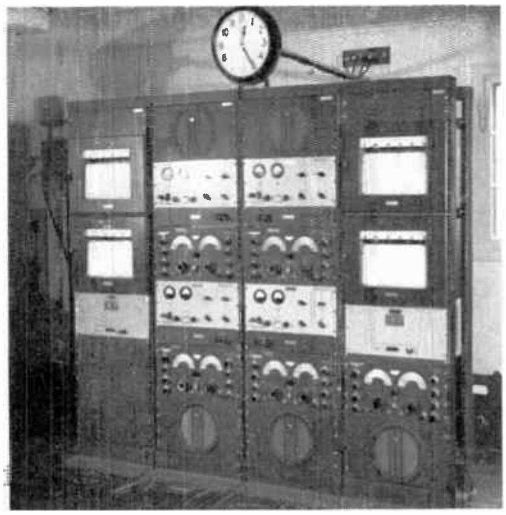
I think a factor that you have not mentioned is also very important, namely, excessive FM tuning drift resulting from receiver oscillator instability. As you are aware, neither the housewife nor the layman can generally tune in FM stations as easily as they are accustomed to tune in AM stations, and this is aggravated by the drift problem. That this problem can be solved even in low cost FM receivers seems apparent from the performance of one manufacturer's table model sets. Other leading manufacturers have licked the problem of drift in their combination sets. Perhaps these companies have in table model FM sets, but I am unaware of it.

As you probably have observed, the Commission has proposed changes in frequency assignments for FM stations in some areas to improve reception and facilitate FM tuning by listeners. The Commission's Bureau of Engineering is continuously reviewing the situation and recommends frequency changes when they are desirable. For example, the withdrawal of some licensees from FM broadcasting often permits improved assignments in their area for other licensees.

The development of the gated beam tube and its probable use in many FM receivers should be an important factor in the growth of FM listening. As I understand it, the characteristics of this tube will not only simplify and reduce the cost of FM receivers, but will also make tuning easier.

I would also like to comment on the problem of AM interference which is referred to by Mr. G. A. Browning in his statement associated with his advertisement of the Browning tuners in your February issue. I fully agree with his statement that "we might as well face the fact that natural and man-made static, and co-channel interference on AM are like death and taxes. They will always be with us." I think it is amply clear at this time that, regardless of

(Continued on page 33)



NEWS PICTURES

TOP: RCA's 44-lb. transmitter-receiver for 152 to 174 mc., intended for main station use or temporary field installation. Circuits are designed to meet requirements of adjacent-channel operation. Output is 15 watts, operating on 115 volts, 60 cycles.

Setup at Ft. Belvoir, Va., with which Bureau of Standards maintains 24-hour recordings of field intensities of four transmitters at Beltsville, Md. Purpose is a continuing study of variations in the absorption of skywave transmission by the ionosphere.

This 8-watt Goodell amplifier has an input switch to provide equalization for audio and video reception, and 78-RPM and LP records. Five-position output switch for 4 to 500 ohms also controls feedback.

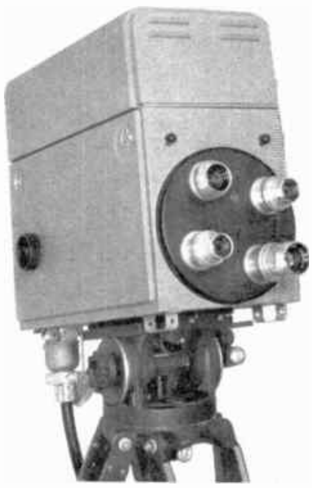
CENTER: Right, Hewlett-Packard 608-A signal generator covering 10 to 500 mc. in five ranges. Master oscillator power amplifier delivers output of .1 microvolt to 1 volt. Left, Model 803-A direct-

reading impedance bridge. Primary range is 50 to 500 mc., but it is useful down to 5 mc. and up to 1,000 mc. Center, VHF detector, model 417-A is a super-regenerative receiver covering 10 to 500 mc.

BOTTOM: Light-weight field camera chain, model CV-2, has been announced by Polarad Electronics Corporation. Brooklyn 11. Camera tube is low-intensity type 5820. Plug-in electronic view-finder clamps on the camera case.

Brains behind rectangular picture-tube bulbs produced by American Structural Products, Toledo, are Dr. Howard D. Vincent, director of product development, and Kenneth M. Henry, vice president and chief engineer of this company.

Development of the Videcon, a camera tube 1 in. in diameter and 6 ins. long, has made possible this miniature TV camera for closed-circuit, industrial use. Monitor unit contains the operating circuits. Can be operated up to 500 ft., producing excellent 525-line images.



MULTIPLE PROGRAM TRANSMISSION

SUCCESS OF FACSIMILE DUPLEX OPERATION ON FM BROADCAST STATIONS MAY OPEN UP MUTIPLE-SERVICE TRANSMISSION — *By* WILLIAM S. HALSTEAD*

BOTH broadcast and communications executives and engineers have shown great interest in the successful, non-interfering operation of facsimile equipment over the FM stations comprising the Rural Radio Network.[1] That is not merely because facsimile may become a profitable adjunct to broadcasting, but because it indicates that an FM broadcast station can add a second program service, or handle communications service to mobile units. And this can be done without causing any degradation to their basic 15,000-cycle program quality, or causing interference with other stations, as demonstrated by the equipment developed by Communications Research Corporation.

The method is not new,[2] although its successful use in conjunction with FM broadcasting is recent enough that its possibilities are not yet generally realized. Accordingly, this paper will present the details of the equipment and circuits used by RRN, and operating information on the frequency-shift method of duplexing.

FS Duplexing:

In the facsimile duplex system developed for the Rural Radio Network, 10-kc. amplitude-modulated subcarrier signals from a standard Finch or General Electric (Hogan) scanner are applied to an audio amplifier, and then rectified, as indicated in Fig. 1. The rectified signal is filtered to remove any trace of the original 10-kc. subcarrier frequency. This is done by a low-pass filter with a cutoff at about 6 kc. The rectified and filtered signal, comprised of DC pulses of varying amplitude, is used to vary the frequency of a multi-vibrator circuit within a range of 20 to 30 kc.

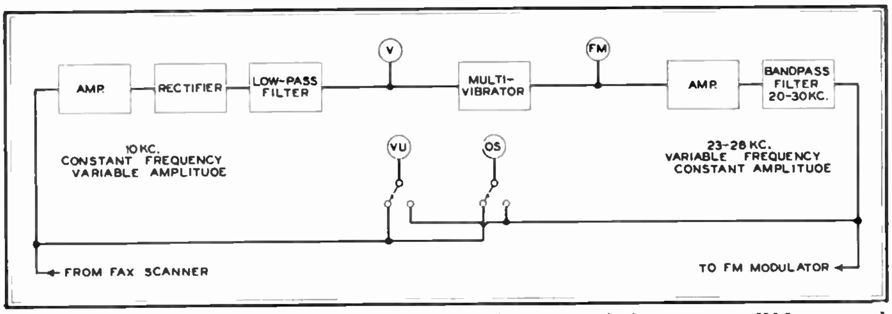


Fig. 1. Basic circuit employed for FS facsimile transmission on an FM network

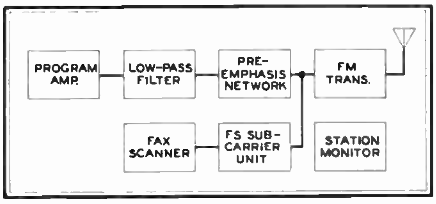


Fig. 2 Duplex aural and facsimile setup

Thus, the 10-kc. subcarrier, amplitude-modulated by the facsimile scanner, produces a new subcarrier of constant amplitude, in the inaudible range between 20 and 30 kc.

In practice, the limits of the frequency-modulated subcarrier are set at about 23 kc. for the white facsimile signal, and at 28 kc. for the black signal. The frequency-shift subcarrier is applied to a cathode-follower and a bandpass filter which permits only frequencies of 20 to 30 kc. to reach the FM modulator of the transmitter. This eliminates any undesired modulation components or harmonics that may be present in the frequency-shift subcarrier.

The FS subcarrier and modulator are connected to the broadcast transmitter between the pre-emphasis net work and the FM modulator, as shown in Fig. 2.

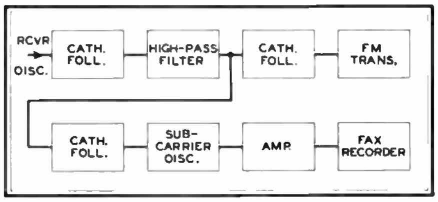


Fig. 3. Facsimile monitor and repeater

Aural program signals are brought to the transmitter in the conventional manner. No circuit changes in existing equipment are necessary, except for the insertion of a low-pass filter at the output of the program amplifier. This is done to eliminate any harmonics above the 15,000-cycle program limit, which might interfere with facsimile information.

Gain controls of the frequency-shift modulator are usually adjusted to produce about 10 per cent modulation of the FM carrier. In order that the total modulation will not exceed 100 per cent, a slight decrease in program gain is necessary. However, a 10 per cent reduction in dynamic range is negligible, since it cannot be detected by the ear.

At the receiving end, the combined audio and facsimile signals are detected and separated by filters, as shown in Fig. 3. Then the facsimile frequency-shift subcarrier must be reconverted to its original AM form. Fig. 3 is a diagram of equipment used in conjunction with a standard monitor receiver for RRN relay operation. It provides for monitoring the facsimile information at each station and, at the same time, retransmitting it to the next station of the network.

As Fig. 3 shows, signals from the discriminator of a conventional FM broadcast monitor receiver are brought, without de-emphasis, to the cathode follower input stage of the facsimile recorder section. A high-pass filter then rejects all audio components, and passes only the frequency-shift subcarrier which occupies a band from 23 to 28 kc. The signal is then split into two channels. One is fed to the transmitter for rebroadcasting the FS subcarrier. The other channel is for facsimile monitoring.

That is, the high-pass filter output goes to two cathode-followers. One is connected to the modulator of the transmitter, beyond the pre-emphasis network. The output of the second cathode-follower is applied to a subcarrier discriminator. This is simply a band-pass filter which as a linear pass-slope between 23-28 kc. The resultant signal, containing amplitude variations corresponding to the original output of the facsimile scanner, is amplified and fed to to the facsimile recorder. The frequency variations are still present, but have no effect on the recorded picture as long as the recorder has a frequency response substantially flat from 23 to 28 kc.

For office or home reception, a simple facsimile adaptor has been developed. A single two-stage amplifier, with a combined high-pass and discriminator filter, provide satisfactory service at a very reasonable cost.

FS Facsimile Equipment:

Fig. 4 shows complete frequency-shift

*President, Communications Research Corp., 250 Park Avenue, New York 17, N. Y.
[1]A very complete study of the Rural Radio Network was presented in "Pattern for FM Profits," *FM and Television*, Sept. 1948.
[2]See Armstrong U. S. Patent No. 2,104,012.

duplex transmitting equipment. The top panel contains the FS subcarrier converter. In the center is an oscilloscope for use as a waveform monitor, and at the bottom is a direct-reading frequency-meter.

The FS converter panel is shown in detail in Fig. 5. Here can be seen a voltmeter and VU meter, and the operating controls to provide proper frequency swing and subcarrier level. Controls not frequently adjusted are behind a hinged nameplate panel.

Fig. 6 illustrates the waveform monitor. Switches are provided so that practically any waveform in the facsimile equipment or the associated broadcast program amplifier can be observed. As in the modulator panel, little-used controls are behind an access door.

A facsimile monitor chassis is shown in Fig. 7. This is used to provide an output for operating a monitor recorder and another output, not demodulated, to the transmitter for rebroadcasting.

Fig. 4. FS duplex transmitter equipment

Multiplexing Circuits:

A schematic diagram of the frequency-shift subcarrier converter is shown in Fig. 8. Amplitude-modulated 10 kc. signals from a conventional facsimile scanner are applied, through an attenuator unit, to a push-pull amplifier. A crystal bridge-rectifier and a low-pass filter convert the signal to a varying DC potential, changing in accordance with the facsimile information. This varying DC potential is applied to the grid of a normally free-running multi-vibrator. Its frequency is shifted from 23 to 28 kc., according to the changing white and black information levels. The amplitude is constant. A twin triode operated in parallel is used as a cathode-follower buffer stage, feeding a bandpass filter. Only frequencies from 20 to 30 kc. are passed, as Fig. 9 shows, and useless harmonics are blocked. The signals at the output terminals of the filter are of sinusoidal waveform, with measured harmonic distortion less than 0.25% at a normal operating level of 0 db on a 600-ohm line within the range of 20 to 30 kc. An attenuator unit is provided at the output.

The equipment has its own power supply, which provides regulated plate voltage for the multivibrator.

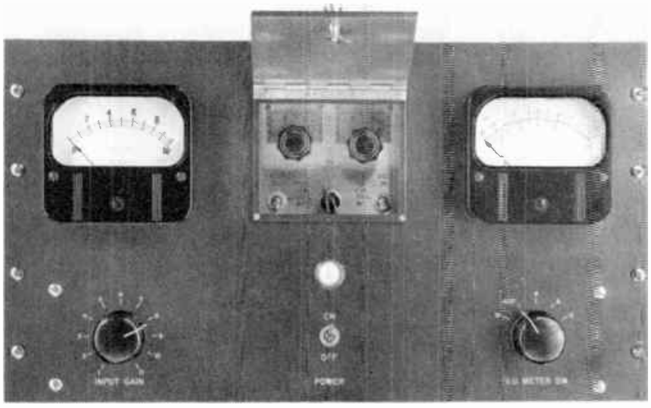
As Figs. 4 and 8 show, a built-in VU meter can be switched to show either input or output levels. Provided also is a DC voltmeter connected at the output of the low-pass filter to show continuously the multivibrator grid voltage. Connections are made at a terminal board for a waveform monitor and a frequency meter.

Fig. 10 shows the circuit for the facsimile monitor unit used in FM relay stations. The discriminator output of the FM monitor receiver, which contains both audio and facsimile information, is brought to the cathode follower input stage. A high-pass filter, which cuts off sharply at 20 kc., removes all audio components of the signal. The response curve of this filter is given in Fig. 11.

The output of the high-pass filter is divided, going through separate gain controls to amplifiers, each feeding a cathode-follower. The lower channel, Fig. 10, feeds the facsimile signal through a transformer and a simple matching network to a terminal board where it is taken to the FM modulator for rebroadcasting.

The signal in the upper, facsimile monitor channel, however, is applied from the second cathode-follower to a discriminator network, shown at the upper right in Fig. 10. The response characteristic of this filter, Fig. 12, is such that a reasonably linear slope is encountered between 20 and 30 kc. Thus the frequency variations from 23 to 28 kc. are reconverted to amplitude variations as in the original facsimile scanner output. The signal is amplified, fed through a final cathode-follower output stage, and is used to drive a conventional recorder.

If it were not for the desirability of feeding the signal to the FM broadcast transmitter without discrimination, the high-pass and discriminator filters could be combined. For use at the ultimate re-



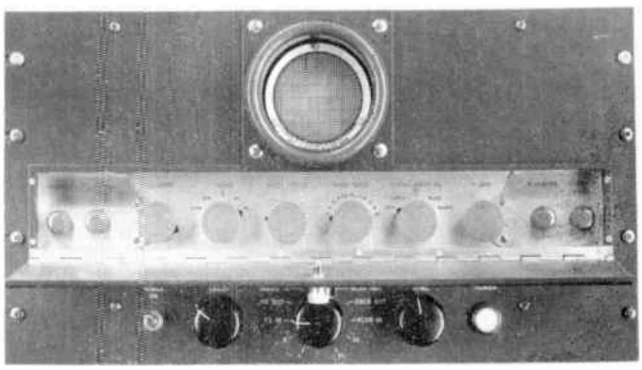


Fig. 5. Control panel for frequency shift operation. Fig. 6. FS waveform monitor for checking both audio and facsimile signals

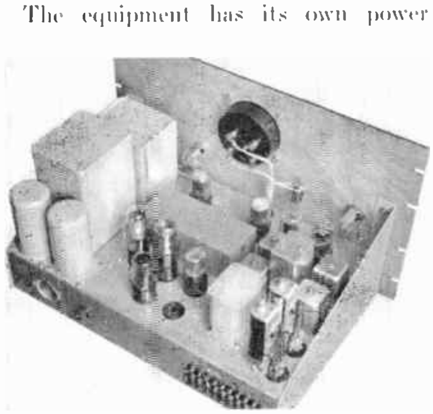


Fig. 7. Chassis of the facsimile monitor

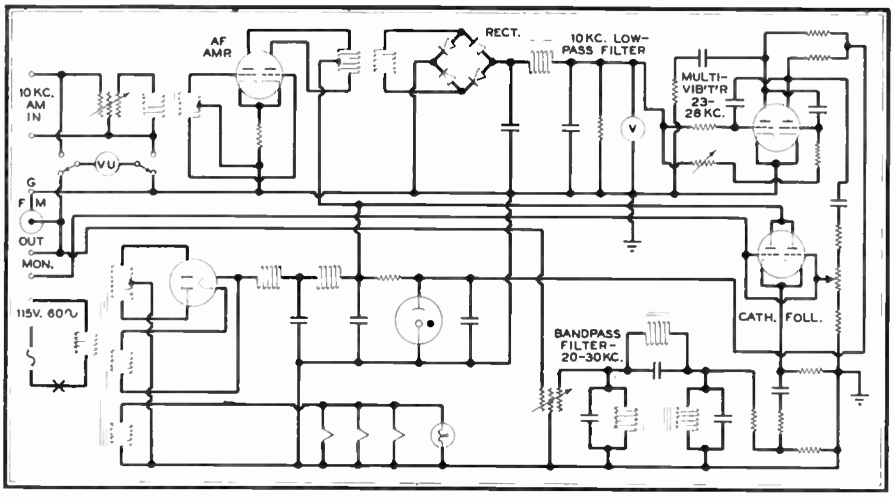


Fig. 8. The schematic wiring diagram of the frequency-shift subcarrier converter

ceiving point — in the office or home — the relay channel is not needed, and a simple adaptor has been designed for this application. Fig. 13 shows a tentative circuit. Only one tube, a twin triode, is used, providing two stages of amplification. The high-pass and frequency-shift discriminator filters are combined in the plate circuit of the first amplifier.

It is assumed that FM receivers used in conjunction with the adaptor will have power supplies adequate for one more tube. Therefore, filament and B voltages required for the adaptor are taken from the receiver, eliminating the need for an adaptor power supply. This results in even greater simplicity and lowered cost. In lots of 10,000, it is estimated that the factory cost of the adaptor would be less than $4.

Tests of FS Operation:

During the tests on Rural Radio Network circuits, the inaudible facsimile sub-carrier signals were superimposed on many of the network's regular aural program transmissions with no difficulty of any nature, and with no deterioration of high-fidelity program signals up to 15,000 cycles. In test transmissions, no report of any audible interference with aural programs was received and, so far as is known, no listener was able to detect the slightest trace of the facsimile subcarrier.

In some tests, the percentage of modulation of the FM transmitter by the facsimile subcarrier was increased as high as 60% without evidence of the subcarrier

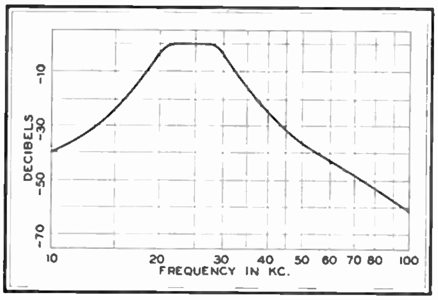


Fig. 9. Characteristic of the filter

at receivers when they were tuned to resonance. Because the facsimile signal may become audible as the modulation level is increased if the receiver is far off resonance, and because of the reduction of the program modulation index by the addition of the facsimile subcarrier, 10% FM carrier modulation by the facsimile subcarrier has been adopted tentatively as an optimum value.

As long as the FS modulation percentage is kept at a relatively low level, the total transmitter and receiver bandwidth requirements are not increased, providing that the total modulation does not exceed 100%.

Extensive tests of signal-to-noise ratios have been made. A General Electric YDA-1 distortion and noise analyzer was used for these tests, together with other standard measurement equipment.

1. Signal-to-noise ratio of a General Electric FM broadcast transmitter, type 4BT1B1: approximately 65 db below 100% modulation.

2. Signal-to-noise ratio of an REL 646-B FM broadcast receiver: 60 db below 1 milliwatt reference level on a 600-ohm line.

3. Signal-to-noise ratio of a GLF FM broadcast receiver: approximately 40 db below maximum audio output of 2 watts.

4. In order to determine the extent to which noise might be produced in a receiver within the range of 50 to 15,000 cycles during facsimile duplex transmission, a 15,000-cycle low-pass filter was connected between the output of an REL FM broadcast receiver and the YDA-1 distortion and noise analyzer. This blocked the facsimile subcarrier signal energy from the noise-measuring circuit. The FM transmitter was modulated by the sub-carrier signals at 10%, as indicated by the station monitor, with no audio signal applied to the transmitter. With the receiver tuned to resonance for normal broadcast reception, no measurable noise whatsoever could be detected in the radio range above the normal backgroupnd noise. It was estimated that if the background noise could have been reduced substantially more than 60 db below the 1-milliwatt reference level the facsimile noise level would have been about 80 db below 1 milliwatt on a 600-ohm line.

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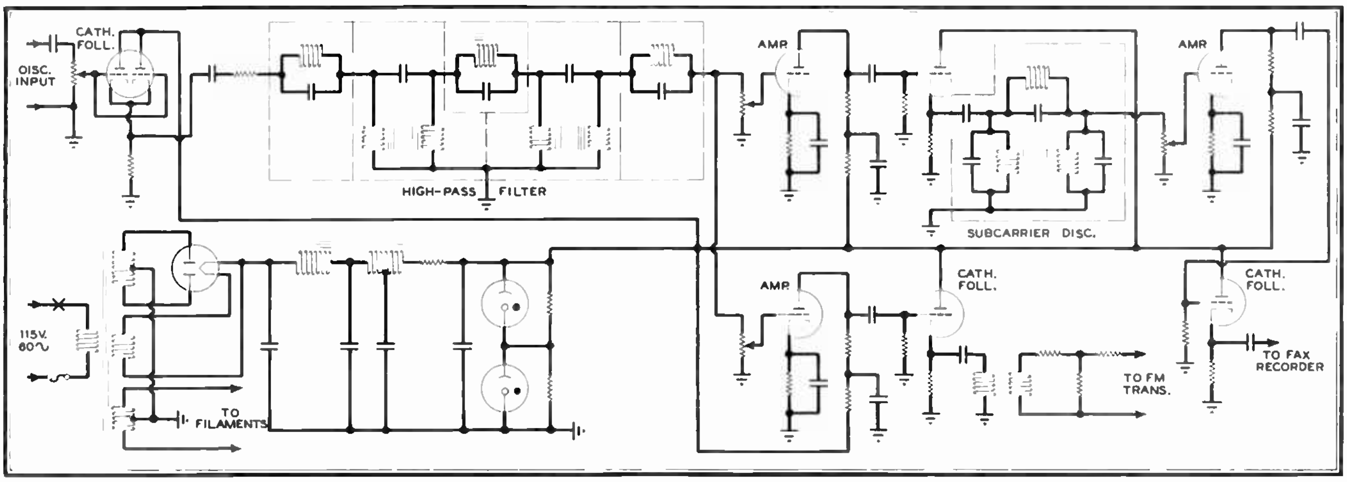

Fig. 10. Schematic wiring diagram of facsimile monitor equipment used at FM broadcast stations for relay operation

JEREMIAH COURTNEY'S* MOBILE RADIO NEWS and FORECASTS

THE FCC continues to turn out products that demonstrate they were frightened by a taxi when giving birth to the Land Mobile Radio Service Rules.

The evidence presented in the mobile allocation proceeding with respect to frequency use by the taxis has apparently left the Commission with the impression that every frequency is as supersaturated as the single taxi channel was at the time of the hearing.

Inter-City Truck Operations:

Latest testimonial to this psychosis was the en banc Commission denial of the petition of the American Trucking Associations to modify the highway truck radio service rules to permit a modicum of metropolitan area use of the 7 frequencies assigned to truck operators.

At present, if you put the handful of truck operators using radio all on the same frequency in a single city, the total message traffic in a month probably wouldn't equal the daily total of one taxi company operating a modest fleet of 50 cabs.

Truck radio traffic is not only much less than that of the taxis but, as the ATA petition explained, the eligibility restrictions thrown around truck radio use by the Commission's Rules are such "that extremely little use will be made of the frequencies assigned to this service."

The ATA petition accordingly asked that the Rule limiting truck radio use to inter-city operators be modified to permit truck operators in metropolitan areas serving inter-city truck lines, railroads, shipping, and air freight terminals to use radio. It was estimated that this would favorably affect not more than 2 to 15% of all the metropolitan truck operators, although only a fraction of that percent would go to the expense of constructing their own radio systems.

Gist of ATA petition appears in following excerpt:

"The Commission, equally with all truck operators, is interested in seeing the frequencies assigned to the trucking industry used by that industry. On the other hand, all truck operators, equally with the Commission, realize that there is probably an insufficient supply of frequencies available to permit all city trucks to operate their own private radio systems. It is submitted that the proper course to be followed lies between these two extremes: 1) of permitting radio only to inter-city operators who, as shown above, cannot afford the extensive equipment investment involved for the limited communications required in inter-city operations; and 2) of permitting radio use to all truck operators without any restrictions, which is not practicable in view of the very small number of frequencies assigned for the use of the trucking industry.

"The intermediate and recommended course to assure trucking industry radio use in proportion to the number of frequencies assigned to its purposes would be to permit those persons engaged in transporting freight to and from trucks engaged in inter-city operations on a route basis outside of metropolitan areas, railroads, ships and airports to be eligible (as well as inter-city truck operators, operating on a route basis, outside metropolitan areas) for authorizations in the Highway Truck Radio Service."

The compromise course of action was recommended on six different detailed counts. No less surprising than the substantive result, however, was the utter lack of consideration afforded the industry position in the Commission's opinion. The curt 22-line opinion, awaited for six months, did not even deign to recite, let alone discuss, the detailed reasons advanced by the trucking industry in support of the mild relaxation recommended. The commission instead simply reaffirmed its faith in its previous judgment, summarily disposing of the ATA petition in the following language: "The Rules in question became effective July 1, 1949, following extensive hearing on the subject of mobile communications. As a result of these proceedings, final rules were adopted for a number of new services, including the highway truck radio service, which reflected the conclusion of the Commission that it was impractical to provide private radio systems for the general dispatch of vehicles in urban areas. The petitioners were afforded an opportunity to be heard on this subject. They have not by their petitions presented any important situations or circumstances that could not have been foreseen at the time of the hearings. The proposal, in any event, does not present a matter of such concern to the public interest as to warrant, in the opinion of the Commission, a change in the Rules or further proceedings at this time."

This attitude is only warranted, of course, if present frequency usage, plus reasonable expansion projected on basis of present frequency utilization demonstrates frequency saturation in prospect. But, so far as is known, Commission has yet to make first frequency utilization study for any mobile service. Furthermore, frequency saturation is the very factor that moves manufacturers to improve equipment so as to use less frequency space. Present attitude therefore not only blocks maximum frequency utilization but removes incentive for equipment improvements as well.

Common Carrier Decisions:

Commission's common carrier mobile radio staff, on other hand is apparently making every effort to insure maximum frequency utilization. Two examples demonstrate attitude prevailing in that sector: Robert C. Crabb, Los Angeles limited common carrier, has been permitted dual-frequency use in two company-operated cars in order to extend range of mobile units in emergencies. For example, when fires occur in valleys where direct communication is impossible, company cars, equipped to operate on both the base and mobile frequencies, can be set up as relays at an intermediate location, thus extending the range of operation. Oddly enough, the Society for Prevention of Cruelty to Animals and an LCC subscriber, inspired this particular application.

Handy-talkie use has been similarly authorized so that LCC subscribers can get closer to scene of emergency operations than possible with radio-equiped vehicles. A Red Cross subscriber pioneered this application. In case of fire or flood, the Red Cross in Portland can now use portable equipment, in conjunction with mobile units, to send instructions regarding the care of the injured or homeless to the base station.

There is some indication that the highly commendable solicitude of the common carrier staff for maximum frequency utilization might be carried to the extreme of recommending the authorization of four limited common carriers in the same city. This would avoid

(Concluded on page 38)

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LOW-COST MOBILE FLEET CONTROL

HOW POSITIVE CONTROL IS ATTAINED, AND FALSE OPERATION PREVENTED IN MOBILE FLEET SYSTEMS AND RADIO RELAY CHAINS. PART 2—By JACK KULANSKY*

Fleet Control Units:

THE basic ideas incorporated in the FTC-1 transmitter unit and the FRC-1 receiver unit are so obvious as to give the impression that the circuits present no particular design problem. It would appear, therefore, that the development of these units should have been a reasonably straightforward project. Actually, many methods were found by which a high degree of dependability could be achieved, but each had one or more elements of uncertainty not amenable to elimination. Since these units have many applications in which they must operate with the certainty of common-carrier telephone equipment, their final design represents the outcome of a major development project.

Specifically, we started with the philosophy that the purpose of fleet control is to improve and facilitate the operation of a communications system. Therefore, the equipment must not introduce new uncertainties of performance, but must increase the overall dependability of the radio installation to which fleet control is added. That end result has been achieved in the units to be described.

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Figs. 3 and 4 show the transmitter and receiver controls, while Fig. 5 presents the circuits in the form of block diagrams.

The Transmitter Unit:

The purpose of the transmitter unit FTC-1, Fig. 3, is to generate an audio-frequency tone, generally of 3,000 cycles, to modulate the transmitter for a period of 200 milliseconds each time the press-to-talk button of the microphone is actuated.

When the control is installed, a connection is made from the carrier-lock initiator relay K_2, Fig. 5, to the transmitter-control relay operated by the press-to-talk switch. When the contacts of K_2 are closed, a transient impulse is passed to the grid of the 12AU7 dash generator tube F_1. This has an "on" time interval of 200 milliseconds.

Simultaneously, relay K_1 keys the 3,000-cycle tone generator V_2. The tone impulse is applied to the input of the transmitter via the buffer amplifier V_3. A bridging transformer is used to match the impedance of the input connections for a carbon microphone, a high-impedance speech amplifier, or a 600-ohm line. When the push-to-talk switch is closed, and the transmitter is turned on, only one 3,000-cycle pulse is emitted.

Under standby conditions, the control unit does not draw high-voltage current, since that is applied to the plates only upon closure of the K_2 relay contacts. The standby current is only the .9 ampere AC or DC filament drain at the nominal value of 6 volts. The actual voltage may vary between 5 and 8 volts without affecting the operation. While the transmitter is turned on, the unit draws plate current of .01 ampere at 180 volts. This can be obtained from the high-voltage supply used for the exciter stages of the transmitter.

The 3,000-cycle tone generator is immune to plate voltage changes between 20 and 300 volts. The effect of such a change is to shift the audio frequency by only .25 cycle.

Up to 1 volt RMS is supplied to a 50-ohm circuit by the output of the buffer amplifier V_3. This is more than adequate, for most transmitters require not more than .2 volt RMS for full modulation. A gain control for the buffer amplifier, adjustable with a screwdriver, is provided on the top of the chassis, as shown in Fig. 3. Once set, it requires no further adjustment. It should be set just under — not over — full modulation, as determined by a modulation monitor. Over-modulation is not desirable, as it will cause the audio tone to be manifested outside the established limits of transmission.

The FTC-1 unit is furnished with a separable connector and a 4-ft. cable of 6 wires for making connections to the transmitter, control relay, and power supply.

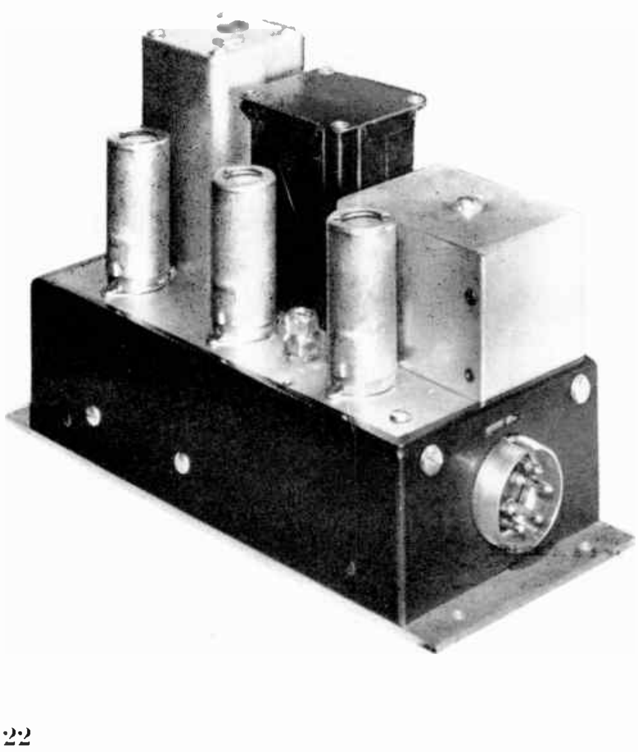


Fig. 3, left: The transmitter control unit delivers an audio impulse of 200 milliseconds duration whenever the push-to-talk button of the microphone is pressed.

Fig. 4, opposite: When an audio impulse of the operating frequency is applied to the receiver control, the muting is removed and held open as long as the transmitter is on the air.

The Receiver Unit:

The FRC-1 unit, Fig. 4, maintains the associated receiver in a muted condition until an impulse of correct audio frequency is received. It then removes the muting connection and holds it open as long as the carrier is on the air. When used for controlling a receiver associated with a repeater transmitter, it switches the transmitter on and off. The unique feature of the control is its ability to reject stray impulses of noise or voice modulation which, otherwise, would cause false operation.

Connection for the input to the control is taken off at the output of the receiver discriminator, prior to the de-emphasis network. The level should be at least .5 volt at the 3,000-cycle tone.

Rectified DC noise voltage is fed to

the input of the threshold carrier-lock-in bias generator, Fig. 5. This is normally obtained from the output of the voltage doubler in the noise voltage circuit used to operate the conventional audio squelch. In some cases, this voltage assumes a nominal positive value of approximately 3 volts in the absence of a carrier signal. It is reduced, sometimes approaching zero, when the carrier comes on. Reduction of the voltage is determined by the carrier signal strength.

An adjustable control is provided on the chassis, Fig. 4, for setting the lowest signal level at which the control unit will operate. A marginal change of rectified noise input to the control produces a 30-db change in the bias voltage developed by the threshold carrier-lock-in bias generator.

Under some circumstances, the rectified noise-voltage input assumes a negative value in the carrier-on condition. This allows a higher level of marginal bias amplification, in excess of that generated if the rectified noise input does not go below zero volts with the carrier on. This is due to the greater voltage swing applied to the grid of the threshold carrier-lock-in bias generator V_2. Otherwise, the operation of the control is independent of either condition.

Again, we have encountered receiver circuits in which the rectified noise output has a negative voltage in the carrier-off condition, increasing in value upon application of the carrier signal. Also, we have found other circuits where the rectified noise may have a high negative value in the absence of a carrier, diminishing when a signal is received. For these cases, too, proper operation of the unit can be obtained by adjusting the control on the chassis.

The method of operation is as follows: When the press-to-talk switch on the transmitter microphone is pressed, the FTC-1 unit instantly modulates the transmitter with a 3,000-cycle tone for a period of 200 milliseconds. This action is so fast that the tone signal ends before the operator can start to speak.

At the receiver, the signal is fed from the discriminator to the 3,000-cycle bandpass filter Z_2 in the FRC-1 control, Fig. 5, and on to the limiter amplifier, V_3. The output of V_3 is applied to the multiple 3,000-cycle bandpass filter Z_1. This operates the pulse detector and relay tube V_1 if the signal voltage overcomes the static guard-voltage maintained on V_1. Also, it must have a minimum duration of approximately 150 milliseconds to operate the delay timer. The latter has a linear voltage characteristic with time, and a rapid hangover decay. Thus, a succession of stray noise impulses cannot develop sufficient average voltage to cause a momentary, false operation of the control contacts of the time-delay relay K_1.

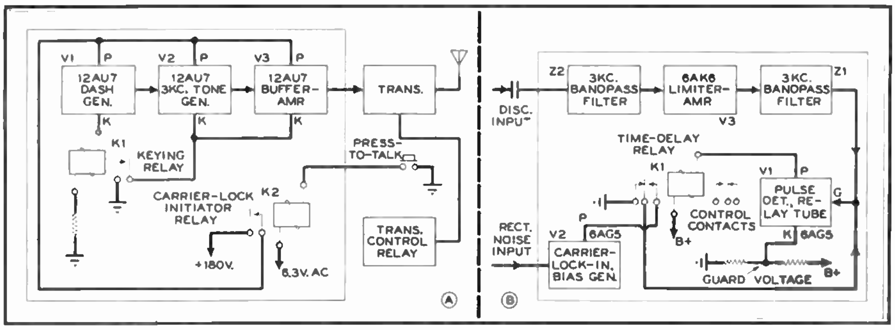


Fig. 5. Block diagram of the control units added to the transmitter and receivers

Crossover attenuation 50 cycles removed from the tone frequency used is of the order of 20 db. This provides more than adequate distinction from extraneous signal voltages, as in a system where two or more tone frequencies are used for different groups of receivers. Moreover, voice transmission intended for one group of receivers cannot operate the control units in the other group or groups of receivers. The characteristics of the filters and limiter amplifier are such that sub-multiple tones of strong signals cannot cause false operation.

When relay K_1 is energized by the output of V_1, two actions result: 1) closure of one set of contacts applies a positive controlling voltage from the threshold carrier-lock-in bias generator V_2 to the relay winding, in order to hold the contacts. 2) Closure of the other relay contacts opens or closes the audio-mute circuit of the receiver, according to the connections required. These contacts can be used also to initiate the operation of a relay transmitter, or a chain of repeater transmitters.

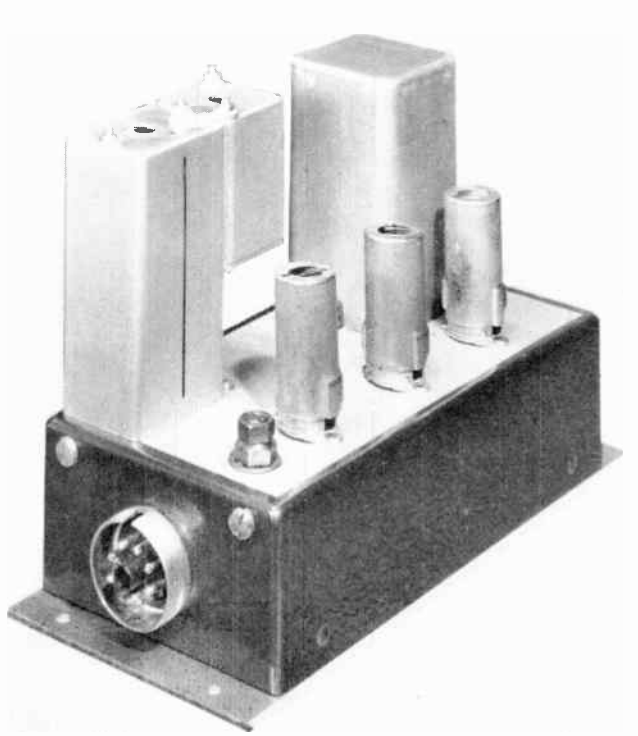
At the end of the message transmission, the carrier goes off and the bias-controlling voltage used to keep relay K_1 in an energized condition drops as much as −30 db, depending upon the setting of the threshold control. This releases relay K_1 and mutes the receiver again, or cuts off the relay transmitter or repeater chain, as the case may be.

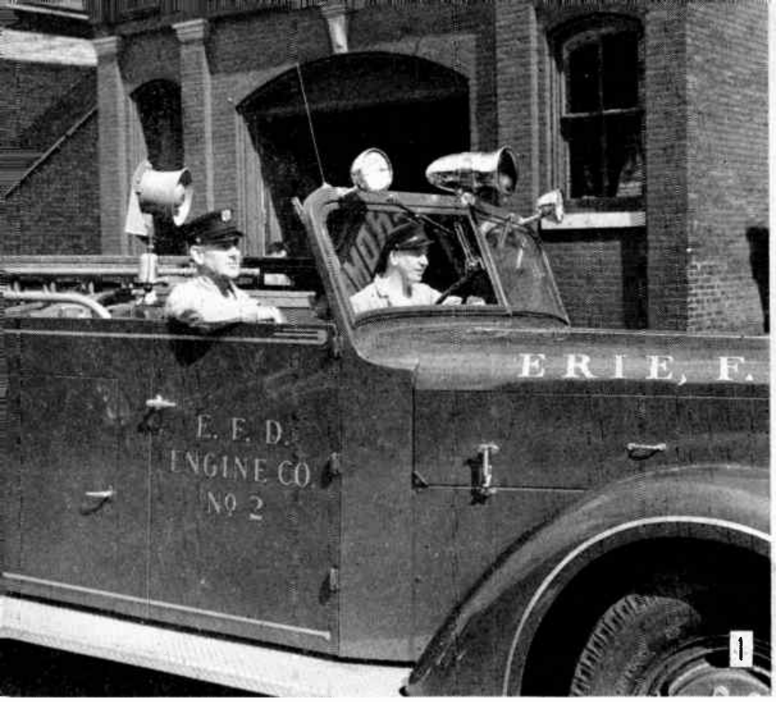
A busy-signal lamp can be added to receivers which are operated in two or more groups. Then a relay is added to control the lamp. The relay coil is connected in the plate of V_2, since this tube operated from the change in the level of rectified noise voltage when a carrier is received. Since the operator at any receiver hears only calls intended for his group, he might otherwise break in on a message being transmitted to another group.

The plate supply for the receiver control should have a nominal value of 180 volts at .006 ampere, with a minimum of 130 volts and a maximum of 250 volts. The filaments require 6 volts at .75 ampere. Variations between 5 and 8 volts will not affect the performance of the control.

It should be noted that when the FRC-1 unit is used in a mobile installation, there is a net reduction in current drain from the 6-volt battery of more than .25 ampere. This results from audio muting in the cathode of the receiver output amplifier.

Thus it is the addition of the fleet control system, unlike other auxiliary equipment, does not increase the battery load.





FM FOR FIRE DEPARTMENTS

HOW FM COMMUNICATIONS EQUIPMENT HAS BEEN INSTALLED ON VARIOUS MAKES OF PUMPERS AND LADDERS USED AT ERIE, PA.—*By* LIEUT. LOUIS RAUB*

SLOWLY, but very certainly, fire departments are coming to recognize the valuable service that radio communications can perform not only while apparatus is rolling and at the scene of a fire, but as a means of tying together the activities of the whole organization. If fire chiefs have seemed unresponsive to the idea of using radio, there is a reason for that attitude. The basic philosophy on which all their signalling equipment has been developed over many years calls for safe-failure operation. That is, their experience has taught them to reject any device which, if it fails, does not signal its defective condition in one way or another.

Since radio is not a closed-circuit arrangement, like the fire alarm boxes, the equipment does not light a light or ring a bell when a tube burns out or a condenser opens up. However, the perfection of two-way radio has largely overcome that objection since, if a call is not answered, it can be presumed that there is an "open circuit" somewhere in the line.

The City of Erie, Pa., now has one of the most completely equipped fire departments in this country, giving Chief Lawrence Scully direct communication from his own car to almost every piece of fire-fighting equipment, and a tie-in with the police department as well. This installation has proved highly successful, and very valuable.

The problems of putting radio on fire apparatus are quite different from those encountered in police patrol cars. Some radio men are inclined to avoid jobs of this sort, merely from lack of experience. Accordingly, the accompanying photos were taken to show typical examples of Motorola installations on various types of ladders and pumpers.

In each case, an auxiliary Motorola speech amplifier and an adjustable loudspeaker are provided so that the microphone for the radio transmitter can be switched over for public address use. Normally, however, the speaker is directed toward the front seat. This arrangement assures that incoming calls can be heard while the apparatus is in motion.

Fig. 1 shows a Buffalo 750-gallon pumper with the radio equipment carried in a water-tight case directly behind the driver's seat. On this pumper, and on all the other installations, the antenna is at the top corner of the windshield.

Fig. 2 illustrates the installation on a Seagrave 65 ft. ladder, and indicates the manner of using the microphone and speaker for calling up to a man in a building. The universal joint of the speaker mounting has a positive-action lock that is not affected by vibration. The case on the running board holds the radio equipment and amplifier.

In Fig. 3, the cover has been removed from the equipment case to show the amplifier and the radio transmitter and receiver. This installation is on a LaFrance 65-ft. ladder, one of the first to be equipped.

A similar arrangement is employed for the Peter Pirsch 1,000-gallon pumper in Fig. 4.

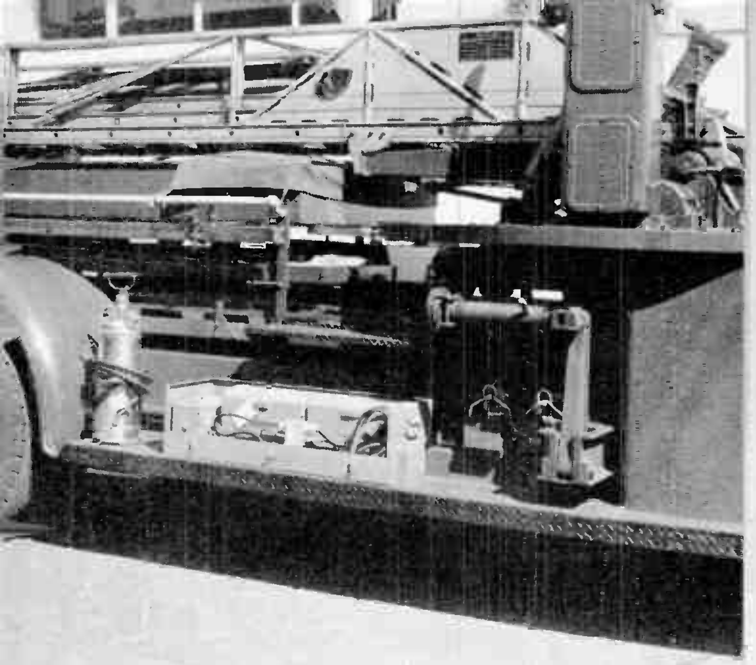
The American LaFrance 1,000-gallon pumper, Fig. 5, does not have a running board, but there was ample space for the radio case behind the seat.

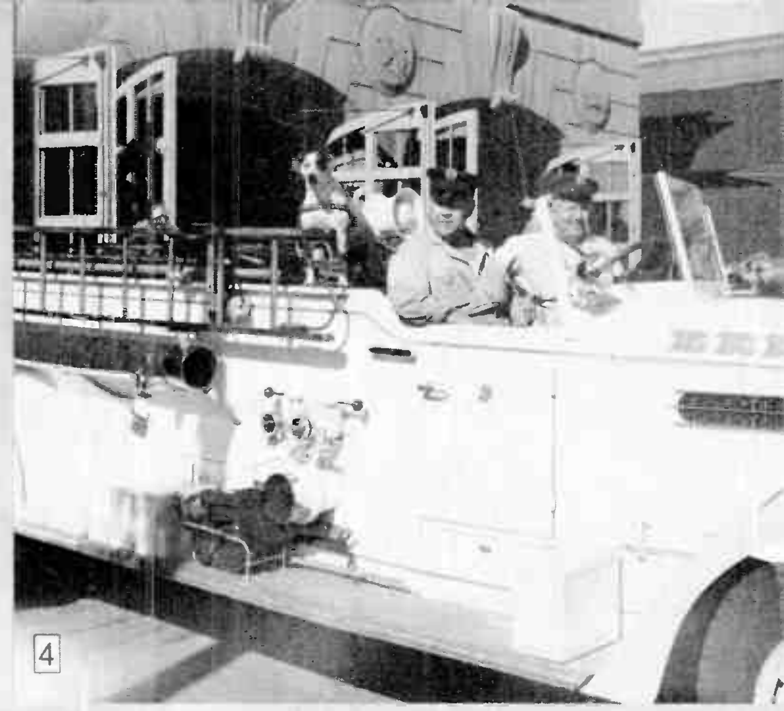
Fig. 6 shows the dashboard of an 85-ft. Seagrave ladder. If you look closely, you can see the two control boxes below and to the right of the handset hanger. One is the regular radio control, while the other is for switching the microphone to the power amplifier. It also has a volume control. The lead to the antenna is secured to the frame of the windshield, running down under the floor and back to the equipment case in the lower left hand corner of the photograph. The lead to the speaker can be seen also. Great care was taken in these installations to fasten the cables securely, at short intervals, particularly as a protection against vibration.

Conditions were somewhat different on the 750-gallon Mack pumper, Fig. 7. There was neither a running board nor a space below the back of the seat. However, there was ample flat space on the body just above the seat, and this served the purpose admirably.

A better view of the dashboard arrangement is presented in Fig. 8. This is on an American LaFrance 65-ft. ladder. The controls for the radio and amplifier are within easy reach, yet they are out of the way and well protected from any damage in service. It is hoped that these examples will be helpful to others who make similar installations.

* Police Department, Erie, Pa.





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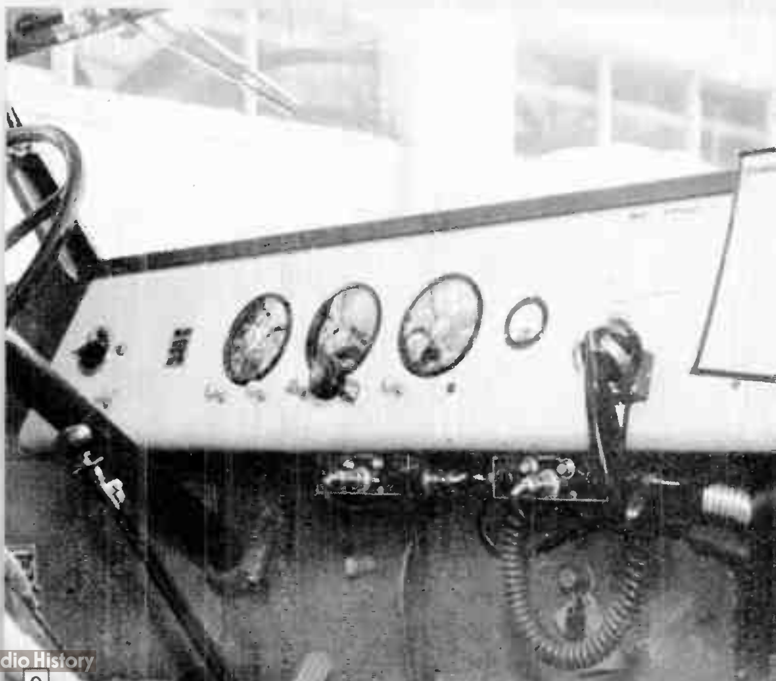

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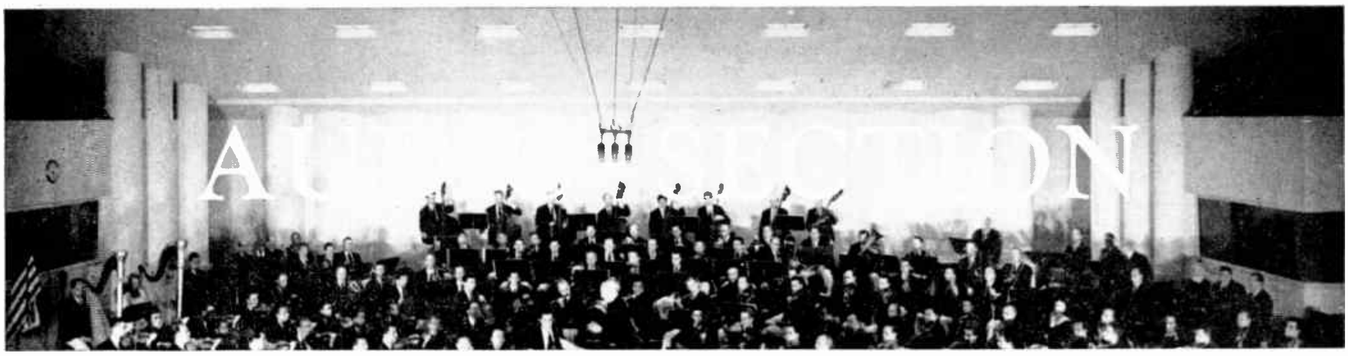


AUDIO RESPONSE AND DISTORTION

EXPLAINING THE FACTORS OF RESPONSE AND DISTORTION IN RELATION TO THE PERFORMANCE OF AMPLIFIERS AND LOUDSPEAKERS— *By* PAUL W. KLIPSCH*

IT can be demonstrated that phase response, transient response, and frequency response are aspects of the same phenomenon. Determination of any one such form of response predetermines the others. Equalization to achieve a given frequency response curve will render a corresponding transient and phase response. Some other means of achieving the same frequency response will produce the same corresponding transient and phase response.

Distortion, also, is exhibited in different forms, all interrelated. A given complete determination of harmonic distortion would uniquely determine the transient and intermodulation distortion. In fact, a complete determination of any form of distortion would determine each of the other forms. Means for minimizing any one form of distortion would reduce other forms of distortion.

The same principles which apply to distortion in circuits and amplifiers apply also to electro-mechanical transducers such as speakers, microphones, and pickups. Phase, transient, and frequency response are mutually dependent in a speaker, just as they are in a circuit.

The above generalizations must not be applied too literally as one considers *field problems* as contrasted with *circuit problems*. Where space, delay (as by delay line or transit time), and lattice networks are involved, phase can be increased independent of other responses. But recognition of other than minimum phase-shift systems is easy, and the special delay or phase effects can be evaluated separately. Generalization for minimum phase-shift networks and systems is valid.

The purpose of this article is to review the theory, and to indicate the applicability of the principles by which phase, transient, and frequency response are aspects of what might be termed "generalized response"; while harmonic, modulation, and transient distortion are different aspects of what might be termed "generalized distortion." Specifically, for example, it is hoped to show that one form of equalization has not the slightest advantage over another means for equalization in reducing phase-distortion as long as the two forms of equalization produce the same frequency response.

Phase & Frequency Response:

There persists a belief that phase shift is some sort of distortion which can be altered at will, independently of frequency response. Actually, however, any frequency response has its associated and unique phase response. There is always a certain minimum phase shift associated with a given response. Phase shift can be increased by means of delay lines, lattices, lattice-derived nets (all-pass circuits), and spacings relative to wave travel, but there is an irreducible minimum phase shift obtained as a result of any frequency discrimination, equalization, or filtering. In the absence of phase shifting devices, a circuit will exhibit minimum phase shift, and is referred to as a minimum phase-shift network.

Phase shift in such networks has been shown by Bode[1] to be uniquely dependent upon the shape of the attenuation curve, referred to here as a frequency response curve. This is summarized, and a correction made, by Terman.[2] Although appearing mathematically formidible, the interpretation is actually simple:

$$Be = \frac{\pi}{12}\left(\frac{dA}{d\mu}\right)_c + \frac{1}{6\pi}$$

$$\int_{-\infty}^{+\infty}\left[\left(\frac{dA}{d\mu}\right) - \left(\frac{dA}{d\mu}\right)_c\right] \log_e$$

$$\coth\frac{|\mu|}{2}\, d\mu$$

where:

B_c is the phase shift in radians at the frequency f_c.

$dA/d\mu$ is the slope of the attenuation curve in db per octave

$\mu = \log_e (f/f_c)$ where f is frequency and f_c is the frequency at which B_c is desired.

$\log \coth \frac{|\mu|}{2}$ = the real part of log $\coth\frac{\mu}{2}$.

Expressed in words, this equation shows that the minimum phase shift is the sum of two components, the first of which is proportional to the slope of the attenuation curve when plotted with decibels as ordinates and the logarithm of frequency as abscissa, and amounts to 180° when the slope of the attenuation curve is 12 db per octave. The second term is determined by an integral of the product of a hyperbolic function of frequency with the difference between the attenuation slope function and the slope at frequency f_c.

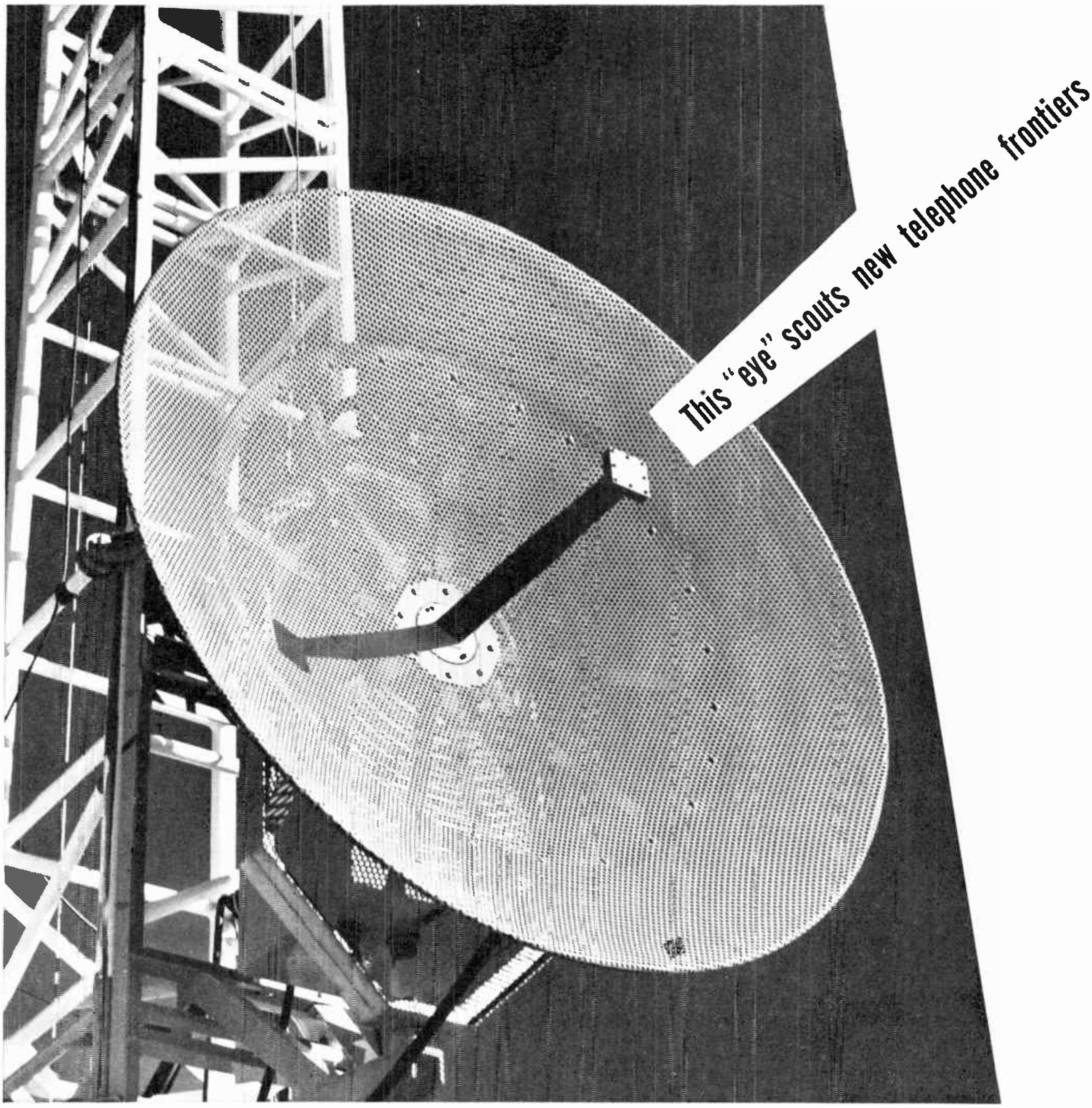
For computation purposes the integration would have to be carried out for the value of phase shift at each frequency to be determined. For the purpose of the present discussion, the expression serves to show that the minimum phase shift is a function of the slope of the attenuation curve, and that any specified attenuation curve must have associated with it a unique minimum phase shift curve.

Evidently, then, there can be no relative merit of one scheme of equalization over another as long as each performs a stated result. Putting it another way, there is no more or less phase shift produced by accomplishing a given equalization by means of discrimination in a

(Continued on page 28)

* Klipsch and Associates, Hope, Arkansas.

[1] H. W. Bode, U. S. Patent No. 2,123,178.
[2] F. E. Terman, "Radio Engineers's Handbook," McGraw Hill, 1943. See pages 218 *et seq*, and particularly equation (125) on page 219


This "eye" scouts new telephone frontiers

feed back loop than there would be by means for obtaining the same equalization in the forward transmission.

The phase shift within a pass band is a function of the attenuation slope both within and outside the pass band. In the case of equalizers in which a given transmission characteristic is specified, say, for the 30- to 1,000-cycle range, the attenuation characteristic below 30 cycles may be of no interest whatever, from the standpoint of equalization, but the phase shift above 30 cycles will depend upon the loss slope below 30 cycles. One group of experimenters observed that a loss below 30 cycles exceeding 6 db per octave produced undesirable listening quality in the audible range. The cause of this effect is not known, but the experimenters attributed at least part of the cause to phase shift. From consideration of transient effects, it appears that transient phenomena may account for part of the effect. The writer is indebted to Messrs. G. W. Ashworth, R. W. Brickenkamp and E. P. Jastram, Jr., who pointed out and demonstrated this effect.

Frequency & Transient Response:

The same dependence exists in the relation between frequency response and transient response as exists between frequency response and phase shift. That is to say, with a given frequency response there is one and only one transient response.

The indicial response is related to the frequency response, according to Bush[3] (equation 389):

$$A(t) = (1/2\pi j) \int_{-j\infty}^{+j\infty} [f(\omega) \exp(\omega t)/\omega]\, d\omega$$

where:

$A(t)$ = the indicial response (transient response to a square wave of long period, or more exactly to a square pulse of infinite duration).

$\omega = 2\pi f$, f being frequency, and

$f(\omega)$ = the frequency response function.

The product under the integral sign is that of the frequency response function, an exponential function of the angular velocity and the reciprocal of the angular velocity.

Interpretation of the transient equation above is that the transient behavior of a network is determined as soon as its AC steady-state performance is defined. While computation and evaluation of the transient behavior might be difficult even with machine integration, the fact remains that there is one unique transient response associated with any given frequency response. Thus a given frequency response fixes the transient response. Whatever means is employed to achieve the given frequency response is immaterial; when the frequency response is specified the transient response is also fixed.

This relation is not dependent upon the use of a minimum phase-shift network, as the transient performance described by the equation is a function of the complex frequency response function which includes the phase function of frequency. Then, the phase function would in turn be fixed by the attenuation function in a minimum phase-shift network.

Distortion:

The only limiting assumption from which the above conclusions are reached is that the circuits or transducers involved are linear, that is, free of distortion.

Distortion may be defined as the generation of frequencies not originally present. Distortion will occur whenever effect is not proportional to cause, that is, whenever the output-to-input ratio is not a precise straight line.

In dealing with low-level circuits where equalization is normally applied, distortion can be reduced to extremely low levels. Working tube circuits well below their load limits results in operating over the straight line portion of their ranges. Negative feedback further reduces distortion. Under such conditions, distortion effects may be neglected and the analyses relating response, phase, and transient effects is practically valid. Negligible distortion should not, however, be assumed, but must be carefully checked and then, if necessary, corrections of bias, loading, and other factors applied.

An audio amplifier usually consists of two distinct sections, a preamplifier where frequency discrimination, tone controls, phono-equalization, and the like are applied, and a main amplifier for delivering large power to a load. Distortion can be kept low in the low-level preamplifier stages, but minimum distortion in the power amplifier imposes severe problems.

From the definition that distortion is the production of frequencies not originally present, harmonic distortion is readily recognized as one form. The same non-linearity that can produce harmonics of a single input wave can also produce modulation products from a plurality of input frequencies. Whenever harmonic distortion exists, modulation or intermodulation distortion can exist also. AM detection is a case in point, where a highly non-linear transducer (rectifier) is used to generate sum-and-difference frequencies in the audio range from the carrier and side-band components of the signal.

Much has been written in recent years on methods of distortion measurement, and there is a growing attitude that intermodulation testing gives a better overall measure than does harmonic distortion testing. However, like the phase-transient-response concept, harmonic and intermodulation distortion are merely different aspects of the same phenomenon. A complete knowledge of one necessarily predetermines the other, though mathematical evaluation of one from a measured known distortion of the other type might be difficult. As to rapidity, or sensitivity, or efficacy, the choice of one method over the other is predicated on the equipment at hand, and how completely the determination is to be made. But a complete knowledge of the distortion characteristics by either method is necessary and sufficient to determine the performance in terms of the other form of measurement.

Note, however, that a complete knowledge of one type of distortion is needed to predict the magnitude of the other. This means, for example, that harmonic distortion at one frequency is not sufficient, any more than the intermodulation distortion at two stated frequencies would be. An amplifier which exhibits 1% distortion (harmonic) at 1,000 cycles might produce 20% distortion at 50 cycles. Intermodulation might amount to 2% using 100 and 5,000 cycles, whereas 20% intermodulation might occur using 40 cycles and 5,000 cycles. Negligible intermodulation might be indicated from harmonic distortion measurements with intermodulation frequencies of 1,050 and 1,100 cycles due to absence of harmonic distortion in the 1,000-cycle region, but the difference frequency of 50 cycles might fall in a frequency range where high harmonic distortion occurs.

Generally speaking, the critical ranges are at the extreme low- and high-frequency ends of the spectrum. High harmonic distortion is apt to occur at low frequencies because of the high exciting currents in the output transformer. High distortion at high frequencies may exist because of 1) high leakage inductance in the output transformer whereby the push-pull tubes are not closely coupled and/or 2) where primary-to-secondary phase shift enters the feedback loop to produce distortion outside the pass-band, with ultrasonic distortion components intermodulating with other audible or ultrasonic components to produce modulation products within the audible range.

Consider a numerical example. Assume a pair of triodes with a plate-to-plate impedance of 2,000 ohms and a load reflected at the output transformer primary of 5,000 ohms. Assume a primary inductance of 20 henries effective at the par-

(Continued on page 35)

[3] Vannevar Bush, "Operational Circuit Analysis," John Wiley and Sons, Inc., 1929. See equation 389, page 177, and other relations in this section.

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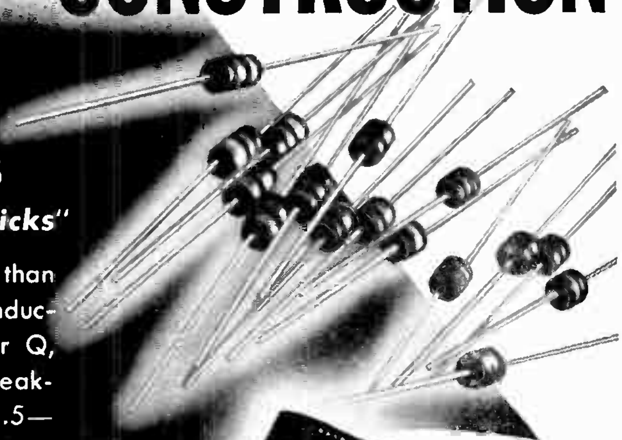

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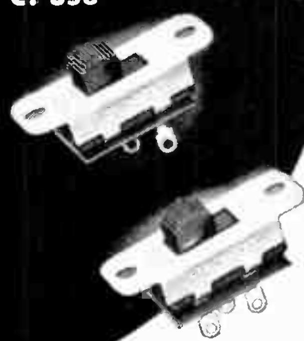

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Electronic Components Division

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MULTIPLE TRANSMISSION

(Continued from page 20)

When sinusoidal AF signals were used to modulate the transmitter, no observable effect such as intermodulation was produced by the subcarrier signal when measured by the distortion meter and an oscilloscope.

5. At the output terminals of the frequency-shift monitor unit, Fig. 10, with 100% total modulation of FM carrier, and 10% modulation by the FS subcarrier swinging from 23-28 kc., the ratio of black signal to aural program signal in the subcarrier channel was about 40 db. and the ratio of white signal to program signal was to 10 to 20 db.

6. Measured under the same conditions as above, the black-to-white signal ratio obtainable was 30 to 40 db. No difficulty was experienced in obtaining dynamic ranges equal to that provided by the facsimile scanning equipment, but satisfactory recordings could be made with the normal operating range of 20 db. Comparisons have shown that there is no significant change in quality as a result of duplex radio relay operation:

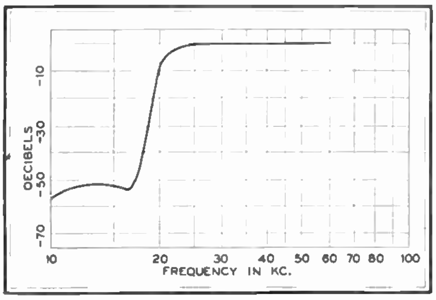

Fig. 11. Filter removes AF components

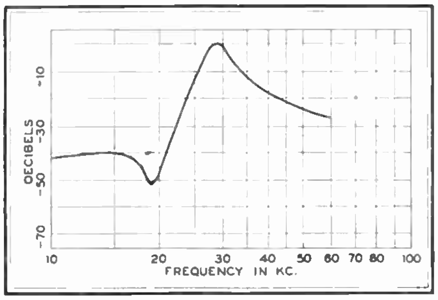

Fig. 12. Slope is linear from 23 to 28 kc.

AM vs. FS Multiplexing:

AM modulation of facsimile subcarriers was in quite wide use some years ago. But in recent years, the FS method has come into general use. An important factor in the adoption of the FS method for commercial operation was the improved degree of subcarrier level control and maintenance of optimum level adjustments, made possible by the constant-amplitude characteristic of the FS subcarrier as contrasted with the continuously-variable amplitude of the subcarrier in AM systems. R. A. Hilferty, chief engineer of Press Wireless, Inc., has this to say about the two systems: "Perhaps the quickest way to come to the point would be for me to tell you that we abandoned amplitude modulation of the subcarrier some ten years ago because of the practical difficulty of maintaining accurate level adjustments. I believe that was the experience of all international carriers engaged in this type of work; and I believe the military also came to the same conclusion. So that today there probably is no remaining AM subcarrier work being done anywhere."

It is evident that the constant-amplitude characteristic of the frequency-shift subcarrier system will simplify the problems of level control and monitoring at broadcasting stations. Further, it is anticipated that when full use is made of facsimile broadcasting, the majority of the recorders will be automatic in operation, with no manual control during reception. To facilitate this unattended recorder operation, automatic level control or limiting of the subcarrier may be desirable. An FS limiter to accomplish this control is simple, non-critical, inexpensive, and reliable. With AM systems, automatic level control circuits present a difficult problem, since they have the inherent disadvantage that limiting action tends to compress the dynamic range between white and black signals.

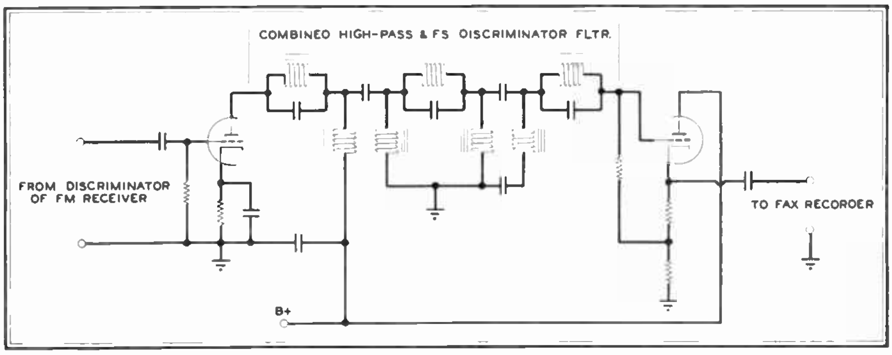

Fig. 13. This adapter for FS facsimile reception in home or office has one tube

(Concluded on page 32)

MULTIPLE TRANSMISSION

(Continued from page 30)

A factor of considerable practical importance is the relative ease with which the dynamic range of the FS subcarrier system can be increased, if necessary. In the case of an AM subcarrier operation, the dynamic range between white and black signals is limited by the noise level of the overall FM transmitting and receiving system, and by the maximum permissible modulation of the FM carrier.

Armstrong and others working with FM multiplexing have demonstrated that with a constant-amplitude subcarrier rather than a variable-amplitude sub-carrier the tendency toward cross-modulation between the audio and multiplex channels of an FM transmitter is reduced. This effect is particularly noticeable when multiple subcarriers are employed. The following statement regarding the FS subcarrier system is found in Major Armstrong's patent 2,104,012:

"In effect, it represents a frequency modulation within a frequency modulation, and the method has great advantages in freedom from certain forms of cross modulation between the channels."

In the laboratory development work on the Rural Radio Network's facsimile system, it was noted that if the amplitude of the facsimile subcarrier was allowed to vary by an appreciable amount, an audible signal could be heard in the background during silent periods in the aural program transmission, when the FM broadcast receivers were tuned off resonance. When all variations in amplitude were removed, no audible trace of the facsimile subcarrier could be heard at 10% FM carrier modulation.

This ability of the FS subcarrier system to minimize difficulties from cross modulation between channels during multiple subcarrier operation is considered to be a factor of great significance with respect to the future of FM broadcasting. It is anticipated that multiple subcarriers will be used for functions such as transmission of facsimile synchronizing signals, and teletype or voice signals for intercommunication between relay or network stations without resorting to separate radiotelephone channels or wire line telephone circuits. Also, Major Armstrong foresaw the use of multiple subcarriers in transmission of a variety of different aural programs from a single FM broadcast station. That this is not of purely academic significance is evidenced by the fact that three national organizations are now giving serious consideration to the future use of multiple subcarriers on FM broadcast transmitters.

SPOT NEWS NOTES

(*Continued from page 8*)

are: Crosley Broadcasting Corp., 10.5 kw. on 105.1 mc.; Atlantic Broadcasting Company, 10 kw. on 106.7 mc.; Debs Memorial Radio Fund, 12.5 kw. on 107.5 kc.; and Ebbetts-McKeever Exhibition Company, 19.5 kw. on 105.9 mc.

Donald G. Haines:

Appointed chief electrical engineer for Sentinel Radio. He was formerly receiver tube applications engineer with Hytron.

Microwave Repeater:

Philco's Industrial Division is in production on a feedback-type repeater operating on 5,925 to 8,000 mc. Designed for common carriers, industrial services, and government agencies, this unit is capable of handling up to 32 two-way voice channels or coded intelligence. Only one Klystron is required for both receiving and transmitting functions in a single direction.

Polarized Relays:

C. P. Clare & Company, Chicago 30, has acquired the distribution of the English Carpenter relays, a polarized type capable of repeating feeble impulses of varying time duration with high accuracy. Of the three sizes, the smallest is no larger than a matchbox. Descriptive bulletins 110-1-2 are now available.

KXOK-FM Ups Power:

St. Louis *Star-Times* has been authorized to increase power on FM from 11.4 kw. to 70 kw. effective radiation. A 574-ft. tower has been acquired from KWK.

Studio Cable Reel:

A rubber-tired, 2-wheel handtruck and cable reel has been brought out by Industrial Electrical Works, Omaha, Neb. Reel has 3 or 4 collector rings connected to the inside end of the cable, so that only the length of cable required need be run out. Capacity is 300 ft. of ¾-in. cable, up to 3,200 ft. of shielded microphone cord. Bulletin A109 gives complete details.

WHAT'S NEW THIS MONTH

(*Continued from page 16*)

whether we do or do not have a North American Regional Broadcasting Agreement, there is going to be an invasion of the service areas, particularly the secondary areas, of the United States AM broadcasting stations by Cuban and Mexican stations and perhaps from stations in the West Indies.

Even with moderate power, many FM stations serve areas that are so much larger than the interference-free nighttime service areas of their associated AM stations that there is scarcely any comparison.

Among broadcast licensees for both AM and FM stations, there are those who feel that they do a better job by independently programming the FM stations, whereas others feel that they should duplicate the service. In my opinion, it adds up to one thing, namely, that the only way a broadcaster can bring his audience to realize the superiority of FM, particularly where he has high nighttime limitation, or the service area is subject to atmospherics, is to duplicate the programs and invite the AM listeners' attention to the fact that the service is available without interference on his FM channel. I can appreciate the difficulty in convincing a listener within the service area of a TV station, who does not have a TV receiver, that he should buy an FM receiver first. I also appreciate the fact that such a licensee has to offer FM as a bonus.

Despite all the problems in FM broadcasting, it is gratifying to note the four important conclusions drawn by Edward L. Sellers of NAB, in his analysis of a

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WHAT'S NEW THIS MONTH

(Continued from page 33)

recent survey which The Pulse, Inc., conducted in the 10-county New York City area:

"FM set ownership continues to increase appreciably.

"FM listeners are loyal listeners; average hours of radio listening seem to hold steadier for FM than for AM, where listeners have a choice.

"Distribution of FM sets is about equally divided between low income groups and high income groups, reaching all socio-economic levels.

"Among numerous reasons given for buying FM receivers, 19.3 per cent are exclusive FM characteristics, such as freedom from static, better reception, desire for FM programs."

I recommend the reading of the NAB report on this subject.

FCC Chairman Coy, speaking at the Annual Radio Conference on Station Problems, University of Oklahoma, March 14, made some very frank comments of interest to broadcasters, and to the industry in general. They are quoted in the following paragraphs:

The [coaxial] cable width used at present is about 2.7 mc. The RCA system requires about 4 mc. An RCA color signal passing through the 2.7-mc. coaxial emerges as a black-and-white signal. . . .

You and I will agree that color is a delightful quality in our everyday life. But let me assure you, with deep feeling, that it is a hydra-headed animal when it is considered in relation to television today.

Color television is a matter of wheels within wheels, or, as Winston Churchill said of Russian foreign policy, "a riddle wrapped in a mystery inside an enigma." . . .

The country is far richer in technological information today as a result of our present hearings. There is no question in my mind but what the Commission's actions with respect to color have moved forward the development of color television by months and years. As a member of the Commission I take pride in the fact that we have been so diligent in looking after the public interest. I am sure that the result will be a far better, far sounder and far more enduring system of television than if we rejected the considerations of color television at the present time and left it to chance to be developed at some unknown place in the spectrum and at some unknown date in the future. . . .

Last fall, the Southern California Association for Better Radio and Television made a survey of television programs scheduled between 6 P. M. and

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WHAT'S NEW THIS MONTH

(*Continued from page 34*)

9 P. M. on Los Angeles stations for one week. It found no crime programs on KFI-TV. Here is what it found on the other stations: "91 murders, 7 stage hold-ups, 3 kidnappings, 10 thefts, 4 burglaries, 2 cases of arson, 2 jail-breaks, 1 murder by explosion of 15 to 20 people, 2 suicides, 1 case of blackmail. Cases of assault and battery were too numerous to tabulate. Also cases of attempted murder. Much of the action took place in saloons. Brawls were too numerous to mention, also drunkenness, crooked judges, crooked sheriffs, crooked juries" . . .

Is it possible that broadcasters who make such a fetish of surveys and audience reaction measurements are overlooking the most obvious and most effective fact-finding technique of all: that of merely sitting down with representative listeners and discussing matters frankly and fully? I think that that would be preferable to sitting cloistered in an ivory tower and trying to hunch audience reaction from charts and graphs. . . .

I would like to close my discussion of bad taste and crime programs on the television and radio by quoting from an observer and teacher of many years ago. It is the Apostle Paul speaking to the Corinthians: "Be not deceived: evil communications corrupt good manners."

REMOTES

(*Continued from page 15*)

they use vertical polarization. Line-of-sight operation is not necessary in the band from 150 to 170 mc.

UHF Mobile Transmitters:

There is also a solid block of 20 channels from 450.05 to 451.95 mc. allocated to mobile pickup transmitters. The model 761 equipment, similar in general appearance to the units shown in Figs. 2, 3, and 4, is designed for that band. Line-of-sight operation is generally required. The power output of the transmitter is 15 watts, but the effective radiation can be increased substantially by the use of a high-gain antenna.

RESPONSE & DISTORTION

(*Continued from page 28*)

ticular operating conditions. At a frequency of 32.7 cycles (the low C_4 of the organ) the transformer shunt reactance would be $\omega L = 2\pi f L = 2\pi \times 32.7 \times 20 = 4{,}100$ ohms.

At 200 volts plate-to-plate, the exciting current would be 200/4,100 or 0.049 ampere which is more than the available plate current of the 2A3 tube. Distortion would occur. But even assuming the tube could deliver such amount of current, the third harmonic of transformer exciting current, usually about 1/3 the fundamental current, would be of the order of 0.016 ampere which, flowing in the 2,000-ohm tube impedance would produce a distortion voltage of 32 volts or 16% of the fundamental signal. Thus, the transformer alone could produce a large distortion. Note that the primary inductance was chosen at such a value that the shunt inductive effect would produce less than 3 db attenuation loss at 32.7 cycles.

Evidently, then, a transformer must be a lot better than would merely meet the requirement of flat response down to a specified frequency. Apparently at least 10 times as much effective primary inductance is necessary to limit distortion to an acceptable value as would be required merely to give a calculated level response curve.

If a speaker to be used in a system is not responsive to low frequencies in the neighborhood of 30 cycles, one might think amplifier distortion at 30 cycles is relatively unimportant. What will actually happen is that the speaker will fail to reproduce the fundamentals, but the distortion components will be propagated and the resultant distortion turns out to be not 16% but several hundred or several thousand percent. The

(*Continued on page 36*)

RESPONSE & DISTORTION

(Continued from page 35)

resulting intermodulation distortion is characterized by that buzz-saw output so typical of many sound systems.

In the example above, no feedback was assumed. If negative feedback is added, overall distortion is greatly reduced as long as the exciting current demanded by the transformer does not exceed the ability of the tube to deliver such current. But when the tube quits — when the plate current bangs up against a limit axis — there is no output to feed back, and the resulting distortion is as great (relatively greater) with feedback as without feedback. With or without feedback, the prime requirement for quality is a good output transformer, and it is noted that the good amplifiers are all typified by having output transformers which are highly developed and usually expensive. Two outstandingly clean amplifiers, the Brook and McIntosh designs, owe their extremely low distortion at least in part to the output transformers used. It might be interpolated that the experimenter and home constructor cannot expect to approach such quality unless he is able to obtain similar transformers.

Loudspeaker Performance:

If a speaker is only responsive down to, say, 90 cycles, it would be well to attenuate frequencies below 90 so that the final stage, output transformer, and speaker will receive but little power below that frequency. Then the output stage and transformer can contribute only limited distortion, and the speaker itself will generate less distortion than would be the case if it were fed power below its operating range.

Generally, the same reasoning which applies to amplifiers is also applicable to speakers. The phase-response relation is directly applicable, as is also the relation between transient response and steady-state alternating current response. In the case of multiple-speaker reproducer systems, the delay difference between units affects the phase response. This case is not the equivalent of a minimum phase-shift system.

Low damping of a speaker will permit a peak of efficiency to occur at and near its mechanical resonant frequency, with a peak of response and a slow decaying transient at this narrow frequency range. Phase shift is very rapid near resonance. Damping of direct radiators is usually accomplished by absorbing the back EMF of the speaker in the plate impedance of a low-impedance amplifier. Again, low damping permits large diaphragm excursion, giving rise to distortion caused both

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RESPONSE & DISTORTION

(Continued from page 36)

by non-linearity of the suspension and non-linearity of the field in which the voice coil moves.

The best form of damping is that provided by acoustic loading, whereby the efficiency is kept at a high level over the entire operating range. The horn, as an impedance matching device, when properly designed and used, provides damping in the form of radiation resistance. The resulting high efficiency permits the driving amplifier to operate at relatively low power levels where distortion is small.

Transient distortion in a speaker or other transducer is difficult to analyze. A pulse excites the system and a decay or hangover occurs at the resonant frequency or frequencies. But under steady-state AC excitation, the output would contain only input frequencies (in the absence of harmonic distortion). To understand the effect, one may think of the pulse as containing the sum of a large number of Fourier components, with the speaker or transducer response being greater for some of these components than for others. Whichever one is excited to the greatest amplitude will be the one which hangs the longest. In this sense, transient distortion is a response phenomenon, rather than being related to the distortion which gives rise to frequencies not originally present. As a step pulse contains all frequencies, a transient hangover at the speaker resonance can not be said to be the production of a frequency not originally present. But the transient hangover, due to low damping, gives rise to large excursions which carries the diaphragm voice-coil into non-linear regions of motion which, in turn, produces amplitude distortion. So it will be seen that a large hangover will result in amplitude distortion even at relatively low levels.

Conclusion:

There is no deep mystery surrounding the relations between phase, transient, and frequency response, nor between various types of distortion. They are interdependent. If the frequency response is adequate and the distortion (total) within limits, phase and transient effects are determined. For satisfactory overall results, it may be necessary to extend the range and limit distortion an octave or more beyond the range used, to eliminate modulation products within the range used, and to minimize phase and transient effects in that range. It should be noted that the best amplifiers exhibit a response range from about 3 to 45,000 cycles or more to keep the range from 30 to 16,000 as clean as possible.

MOBILE RADIO NEWS

(Continued from page 21)

some comparative hearings now in the offing, but would sound the death-knell of service because it would automatically limit each carrier to a single channel.

At present, FCC is assigning only two of the potentially usable four channels because of inability of present equipment to work satisfactorily in same area on 60-kc. separation. More important than equipment limitations, however, is the economies of the situation. All available evidence now points to the need of two channels for each carrier. This economic essential can be obtained simply by permitting each of two carriers to expand on their adjacent channels as and when equipment performance permits such operation in same city. Each carrier would then work out his own equipment replacement problems in order to utilize the second channel.

It has also been suggested by the sales manager of a leading manufacturer that each of two LCC's continue to use his present channel for local service; that the third channel be assigned to both carriers for inter-city traffic; and that the fourth channel be assigned to first carrier demonstrating the need for an additional channel for local communications.

This plan has much to recommend it. Common inter-city channel use by all carriers would insure inter-city truckers' service in every city in the Country.

In addition to nation-wide availability of service, expense of two-channel equipment would also be eliminated. At the same time a very definite incentive, the second local channel, would up service in his city.

Miscellaneous Notes:

President Truman's Communications Policy Board, headed by ex-FCC Commissioner Irvin L. Stewart, now president of University of West Virginia, has begun its overall study of frequency uses by Government and industry.

Use of 420 to 460 mc. by Aeronautical Radio-Navigation Service has been extended to February 15 1953, despite National Police Radio Committee objection to further occupation of this band by air service. It is hoped that this is final extension.

Andy Ring must go through a hearing before the FCC will decide whether his company's use of radio in the adjustment of directional antennas for broadcast stations falls within "production and construction" eligibility requirements of Special Industrial Radio Service.

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Heater Voltage	6.3 volts
Heater Current	1.0 amperes
Amplification Factor (Average)	100
Direct Interelectrode Capacitances (Average)	
Grid-Plate	1.95 μμfd.
Grid-Cathode	6.50 μμfd.
Plate-Cathode	0.035 μμfd.
Transconductance ($i_b = 70$ ma., $E_b = 600$ v.) (Average)	22,000 μmhos

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Class-C FM Telephony or Telegraphy
(key-down conditions, 1 tube)

Maximum Ratings

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D-C Cathode Current	125 Max. Ma.
D-C Grid Voltage	−150 Max. Volts
Peak Positive R-F Grid Voltage	30 Max. Volts
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Plate Dissipation	100 Max. Watts
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