Some Applications of the Type "J" Carrier System *

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Previous papers before the American Institute of Electrical Engineers describe the development of a twelve-channel type J Carrier System. This paper discusses some of the practical problems encountered in extending the circuit capacity of existing open-wire lines by the use of this carrier system.

The first systems of this type were placed in commercial operation late in 1938. One of these systems is discussed in detail from the standpoint of obtaining satisfactory operation with the most economical arrangement of new and existing facilities.

A TWELVE–CHANNEL carrier telephone system for open-wire lines was described before the American Institute of Electrical Engineers early this year,[1] and a discussion of the requirements of line facilities for its operation is being presented.[2] Since the first three systems to be placed in commercial operation are located in Texas, it seems appropriate to present to the Southwest District Convention the major problems arising from the practical application of this type system on existing open-wire plant.

In 1935 it became apparent that existing open-wire facilities on some of the major toll lines in Texas would soon be exhausted. In the case of the Dallas-Houston, Dallas-San Antonio, and Dallas-Longview lines, current growth and requirements for the future indicated that while a toll cable would probably have to be provided ultimately, the development of the open-wire twelve-channel J carrier system makes available an arrangement for obtaining a large number of additional circuits over the existing lines to provide for the immediate requirements and also permit postponement of more costly relief measures for a number of years.

The type J system operates in a frequency range above that of the three-channel type C carrier system and can be superposed on the same conductors with the type C, thereby providing a total of sixteen circuits from one pair of conductors. However, conductors suitable

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[1] "A Twelve-Channel Carrier Telephone System for Open Wire Lines," by B. W. Kendall and H. A. Affel, Winter Convention, A.I.E.E., 1939. *Bell System Technical Journal*, January 1939.

[2] "Line Problems in the Development of the Twelve-Channel Open-Wire Carrier System," by L. M. Ilgenfritz, R. N. Hunter, and A. L. Whitman, District Convention, A.I.E.E., Houston, 1939. This issue of the *Bell System Technical Journal*.

for type C carrier operation are not necessarily satisfactory for the operation of the new system.

The three lines under consideration were practically of the same construction, being twelve-inch phantomed lines originally built for voice frequency circuits only and later modified for the application of type C carrier systems. Over lines of this type, it is practicable to operate a single type J system without any material change in the line wire because no crosstalk considerations are involved, although it is necessary to select by transmission measurement pairs which are free from absorption effects. Where more than one system is required a transposition arrangement has been designed for use with line conductors of a non-phantomed pair spaced six inches apart and thirty inches between conductors of horizontally adjacent pairs. This design can be used either for new wire or for existing wire retransposed, and can be applied without regard to the existing phantomed transposition design, thereby permitting respacing and retransposing any portion of the existing wire, a phantom group at a time if desired.

Advance Engineering

With these operating limitations a review of the circuit requirements established a plan to place a J carrier system on one of the phantom groups of the Dallas-Longview line during 1938. This system would not only provide sufficient circuits to meet the additional requirements but would furnish sufficient spare circuits to release one phantom group of twelve-inch wire for respacing and retransposing. This plan was not applicable to the Dallas-Houston and Dallas-San Antonio lines since circuit relief was required for the 1937 business, and the J carrier system would not be available until 1938. These lines each consisted of five crossarms of 104 mil wire over the greater portion of their length. An inspection showed that, although the poles were of sufficient strength to support additional crossarms, it would be difficult to maintain the necessary wire clearance with an additional crossarm below the existing wire and also that new wire so placed would be susceptible to interference from possible breaks in the wire above.

The solution of this problem was the addition of a crossarm two feet above the others on a simple extension fixture. This fixture shown in Fig. 1 consists of a four-inch steel "H" beam fastened to the pole by the through bolts which also support the two upper crossarms. By placing four pairs of six-inch spaced conductors on the new crossarm and by using four type C carrier systems, sixteen additional circuits were obtained to furnish the circuit relief for 1937 and, in addition to

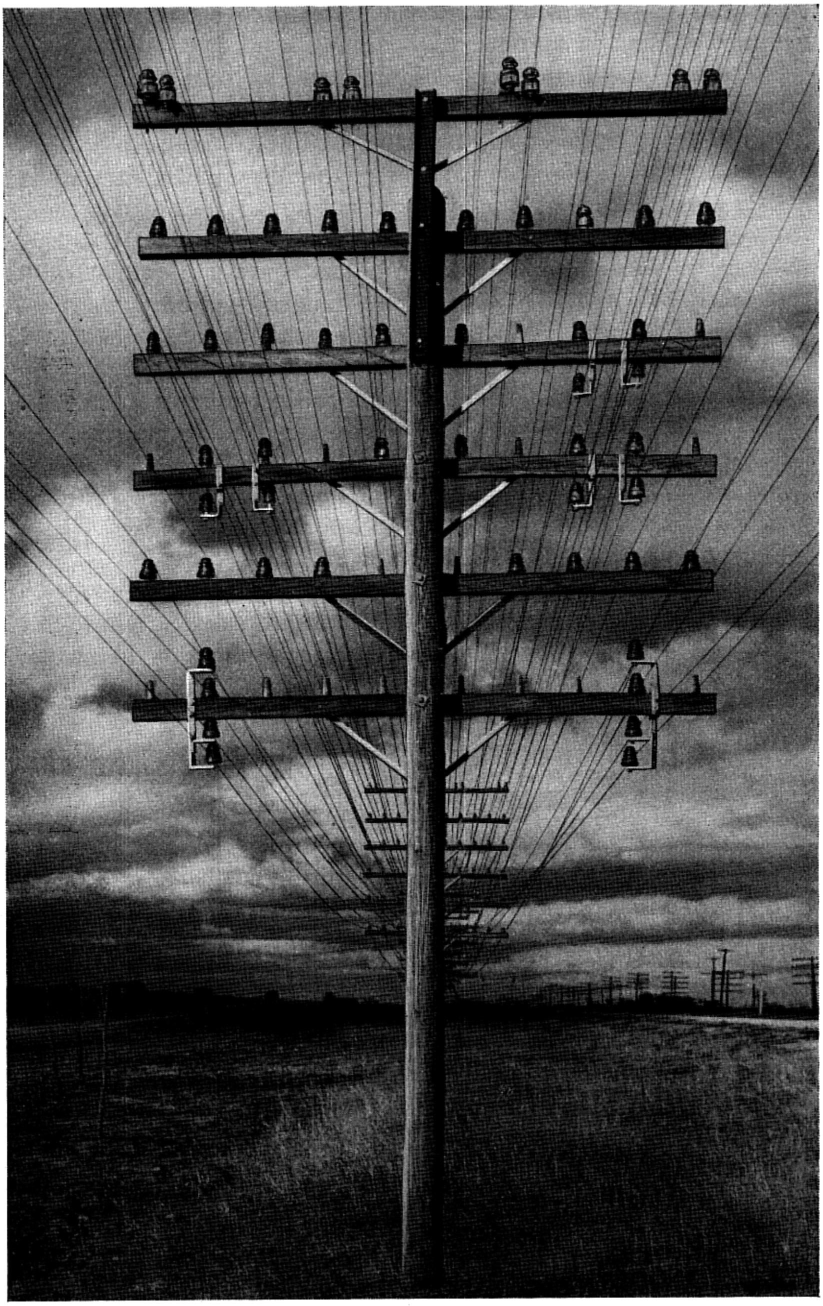

Fig. 1—Typical pole with extension fixture.

the immediate relief, four suitable J carrier paths were provided of which one on each line was needed in 1938. Figure 2 is a typical pole head and shows how the ultimate circuit capacity of this open-wire plant has been expanded from 69 to 133 circuits by the addition of one crossarm and eight conductors. The use of 128-mil wire instead of 104-mil wire provides greater strength and, considering the particular location, reduces the probability of interrupting sixteen circuits by a single wire break or other physical interference.

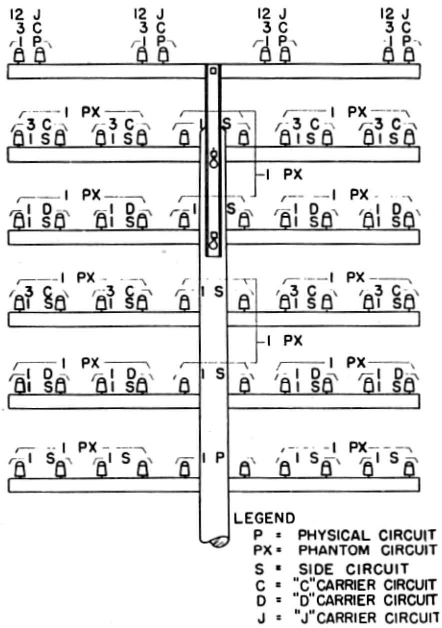

Fig. 2—Pole head diagram showing circuit capacity of the Dallas-Houston and Dallas-San Antonio lines.

The program of placing three type J carrier systems in service in Texas during 1938 was established. Figure 3 is a map of a portion of the state showing the routes of the lines and the principal cities along the routes. Since the length and attenuation of each of these lines are such that the carrier systems can not operate without intermediate amplification, it was necessary that the number and locations of repeater stations be determined.

Typical System

The layout of a particular system is largely controlled by available repeater gain, existing entrance cables, line attenuation under normal

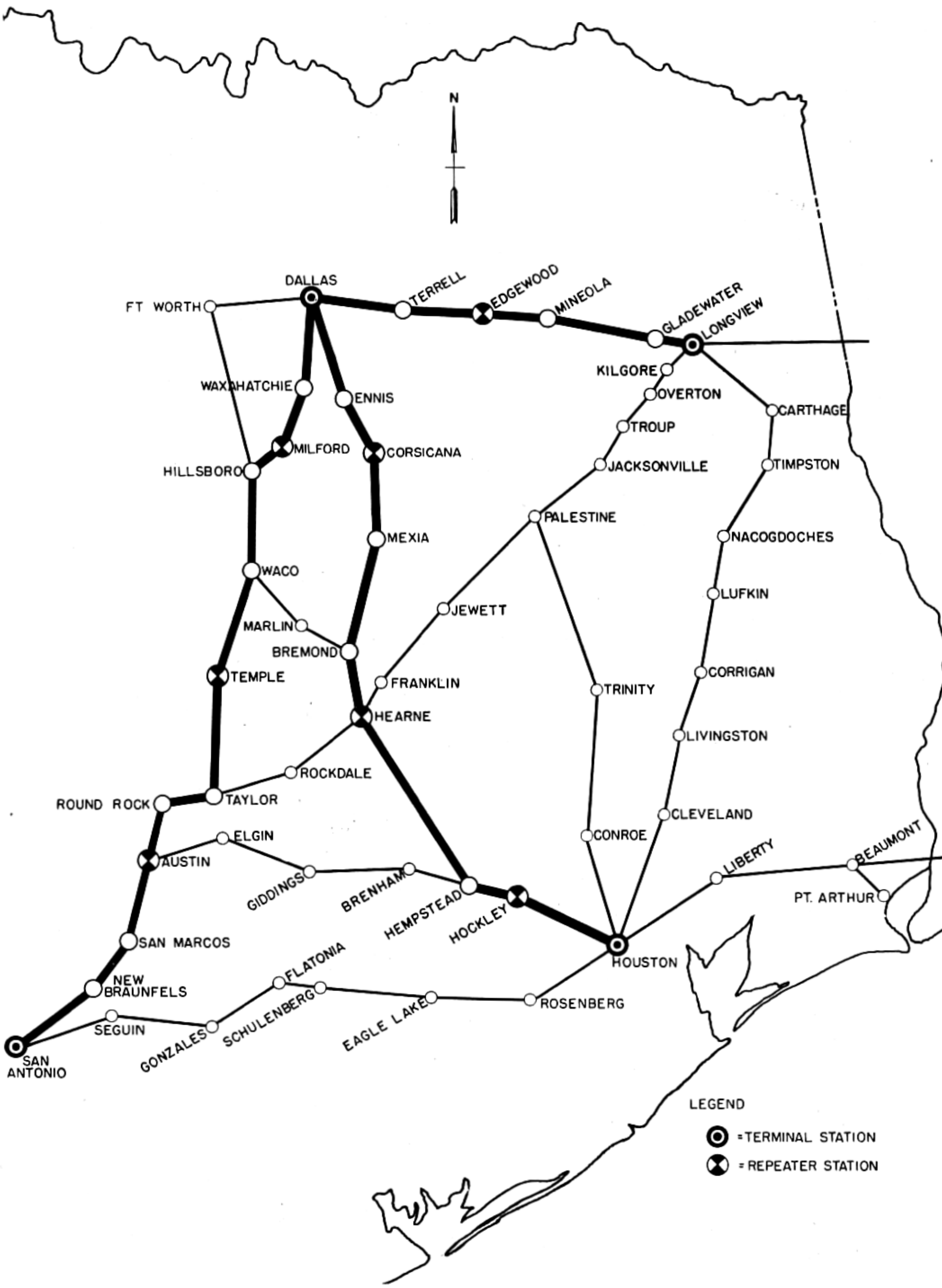

Fig. 3—Routes of toll lines on which the J carrier systems are applied.

and adverse weather conditions, location and availability of existing telephone buildings, and availability of commercial power for new buildings. Line attenuation is increased greatly by deposits of ice on the wire during sleet conditions. Although data are available regarding the frequency of large deposits of ice, there is very little information as to the amounts or frequency of occurrence of small deposits. Under normal wet weather conditions the maximum attenuation of six-inch spaced 128-mil facilities at 140 kilocycles is 0.35 db per mile.

On the Dallas-San Antonio line the facilities available consisted of 286 miles of six-inch spaced 128-mil copper wire and 42,000 feet of 16-gauge non-loaded paper insulated cable. Using repeaters having a maximum amplification of 45 db in each direction of transmission, the provision of two intermediate repeaters would provide sufficient gain to take care of the wet weather conditions with no extra margin; three repeaters would provide 45 db margin and four would provide 90 db margin for the overall system. Considering the location of this line and the small probability of obtaining large deposits of ice in accordance with past experience, it was decided to select tentatively three intermediate repeater stations which would provide sufficient gain to take care of attenuation up to about 0.5 db per mile as compared to the wet weather value of 0.35 db per mile.

For type C operation over this line, only one type C carrier repeater point is required, and it is at Austin. Considering the availability of power equipment and operating personnel and the possibility of future J carrier terminals being located at Austin, it is desirable that this be one of the repeater points on the J system. A division of the attenuation of the facilities north of Austin indicated that the other stations should be in the vicinity of Temple and Milford.

At these repeater stations amplification is needed only on the type J system and the other circuits on the line pass through these stations without amplification. Under these conditions energy may be transferred from the output of one type J repeater to the input of the same repeater or to the input of a repeater on another J system via crosstalk paths involving the wires which are not used for type J systems. The effect of this transfer of energy is accentuated by the fact that there is a large difference in transmission level between the output of one type J repeater and the input of the same or another repeater. In order to minimize these effects it is necessary that all wires on the line be given special treatment, including a gap in the toll line, longitudinal choke coils in all wires at terminal poles and crosstalk suppression filters in the non-J pairs in the repeater station itself. In selecting locations for repeater stations, consideration must also be given to the possible coupling between type J systems by interaction paths involving other conductors adjacent to the toll line.

Before definite selection of repeater station locations may be made, it is necessary that each repeater section be checked in detail and in this check the entrance cable arrangement may be controlling. The newly developed spacer insulated spiral-four cable, either loaded or non-loaded, or non-loaded pairs of the conventional paper insulated cable may be used between the open wire and equipment. Generally the existing voice and C carrier circuits use loaded entrance cable pairs and in most cases a change to non-loaded facilities would require extensive rearrangements in these circuits. In order to use non-loaded pairs for the J carrier and leave the C carrier and voice on loaded facilities, filters are placed at the terminal pole to separate the J carrier frequencies from the C and voice frequencies at that point. A limitation on the use of existing cable is that suitable pairs must be selected by crosstalk measurements and balanced at 140 kilocycles to meet the requirements of the system. The paper insulated conductors have the largest attenuation of any of these facilities, and the loaded spiral-four the least. The various entrance arrangements from the open wire to the office equipment are described in more detail elsewhere.[2] The choice of the facility used in any particular case will depend upon the resultant overall economy.

The large number of non-loaded pairs in the existing 1.6 mile entrance cable at San Antonio indicated that sufficient pairs could be selected which would be satisfactory from the crosstalk standpoint for J carrier operation. Six pairs were subsequently selected and balanced.

At Austin a single toll entrance cable, one mile in length, with two complements, terminates the line from the two directions. Although the two complements are separated by a layer shield, this cable is not suitable from a crosstalk standpoint for operation of the J carrier in and out of the office; therefore, at least one additional cable is required from the central office to the toll line. For this purpose a new non-loaded spiral-four entrance cable was indicated for the type J system with the type C and voice circuits continuing to use the existing cable. The separation of the type J circuits from the non-J circuits on the same pairs is accomplished by filters which are located in a small building at the junction of the toll line and the entrance cables. The use of a single entrance cable for the non-J wire in both directions on the telephone line indicated that it might be necessary in the future to use crosstalk suppression filters at this point. Accordingly, the filter hut was made large enough to include future crosstalk suppression

[2] Loc. cit.

filters if required as well as the line filters which separate the type J from the non-J circuits.

A repeater station at Temple could have been located in the existing central office or could be located in a separate building in or near the city. In either case a new power plant was needed since the existing plant could not be economically modified to serve the J carrier repeaters. The telephone line is continuous through the city, only those wires used for Temple circuits being terminated in the office through one entrance cable 0.6 mile in length. This cable is not suitable for J operation in both directions, which would require one additional cable if the repeaters were located in the central office. Numerous signal and supply lines in proximity with the telephone line within the city offered interaction crosstalk complications. A separate repeater station near the toll line in or near the city avoids the placing of a long entrance cable, reduces the overall system attenuation, and eliminates the problem of interaction crosstalk from paralleling lines. Other factors including cost showed very little difference between a separate station and placing the repeaters in the central office. An unattended station near the toll line was indicated.

A common entrance cable at Dallas terminates the wire on both the Houston and San Antonio lines, the terminal of the Houston line being 2.9 miles from the central office, and of the San Antonio line one mile further. This cable previously had been placed in three different sections, each section having a different make-up, and there was considerable doubt as to the number of suitable pairs for J operation that could be obtained. The use of either a loaded or non-loaded spiral-four cable would not improve attenuation sufficiently to change the number or materially alter the locations of the repeater stations from those tentatively selected, but would provide some additional margin for sleet conditions. The expense of loading the spiral-four cable, if placed, could not be justified by the improvement in overall attenuation. Using either non-loaded spiral-four or existing non-loaded paper insulated conductors requires filters at the open-wire terminus. With these considerations, it was decided that suitable pairs would be used in the existing cable until exhausted. Subsequent crosstalk selection tests have indicated that twelve pairs, six for each line, are available.

Since there was no suitable central office building at Milford, the repeater station in that vicinity must of necessity be in a new building preferably near the toll line. Commercial power is available only near the town, forcing a tentative location to be selected at the edge of the city.

TABLE I

DISTRIBUTION OF GAIN AND LOSS BY REPEATER SECTIONS

Repeater Section	Cable		Open Wire			
	Length Miles	Loss db	Length Miles	Wet Weather Loss db	Maximum Tolerable Attenuation in db per Mile at 140 KC Using: 45 db Repeaters	Maximum Tolerable Attenuation in db per Mile at 140 KC Using: 75 db Repeaters
Dallas-San Antonio System						
Dallas-Milford	3.9 mi., 16 ga.	17.50	49.2	16.4	0.560	1.165
Milford-Temple	Nominal	Nominal	84.7	27.3	0.532	0.885
Temple-Austin	1.1 mi., Spiral-4	2.20	74.4	24.8	0.575	0.980
Austin-San Antonio	{1.1 mi., Spiral-4; 1.8 mi., 16 ga.}	10.30	78.5	26.2	0.635	0.825
Dallas-Houston System						
Dallas-Corsicana	2.9 mi., 16 ga.	13.20	52.5	17.5	0.610	1.175
Corsicana-Hearne	0.5 mi., 16 ga.	2.25	90.5	30.2	0.484	0.805
Hearne-Hockley	Nominal	Nominal	85.6	28.6	0.545	0.875
Hockley-Houston	5.6 mi., 16 ga.	25.20	29.1	9.7	1.190	1.700
Dallas-Longview System						
Dallas-Edgewood	1.4 mi., 16 ga.	6.30	55.3	21.0	0.984	1.240
Edgewood-Longview	0.5 mi., 16 ga.	2.30	69.7	26.5	0.614	1.040

With these selections of entrance cable facilities and tentative repeater station locations, the distribution of gain and line loss by repeater sections is shown in Table I. A satisfactory distribution of line loss has been obtained and an analysis of these data shows that further improvement is impracticable. Therefore, the tentative repeater station locations were adopted.

Figure 4 is a diagram of the major line and equipment parts of the Dallas-San Antonio lead. The J carrier path is shown by heavy solid lines, the C and voice on the same wire with the J by light solid lines, and all other circuits, classed as non-J, by dotted lines. Figures 5 to 8, inclusive, show in more detail the arrangements at the huts and repeater stations. The figures for the Dallas Hut and Temple Repeater Station are typical, and huts and unattended repeater stations not shown differ from these only in minor details. It will be noted that all wire on the toll line is brought through the repeater stations while only that wire on which J carrier is superposed is routed through the huts except at Austin where all wire to the north is brought through the hut to allow the future application of crosstalk suppression filters if required. For both huts and unattended repeater stations, short lengths of loaded spiral-four conductors are used from the six-inch spaced wire at the terminal poles to the equipment in the buildings. A single continuously adjustable load unit is used for each pair and is located with the equipment. Paper insulated pairs under the same cable sheath as the spiral-four conductors are used for the non-J wire.

As previously mentioned, the conditions at Austin were complicated by a single cable for existing circuits and a new cable for J carrier in both directions. Figure 9 is a diagram of the existing and new cables to the filter hut and terminal poles, and Fig. 10 shows the interconnection of circuits and equipment used at the filter hut, terminal poles, and central office.

Terminal and repeater equipment in existing offices is located in space adjacent to other equipment terminating toll circuits, and makes use of the common office equipment and power plant. The relation of the J carrier terminals to the other equipment in the Dallas Toll Office is shown in Fig. 11.

The new repeater stations and the filter huts are arranged for unattended operation. The equipment in the filter huts is such that no adjustment or attention is required other than periodic inspections. In the unattended repeater stations the power supply equipment is automatic in its operation. Although periodic maintenance attention is necessary, it is desirable that any abnormal condition be recognized as soon as practicable and a system of alarms has been provided from each unattended station to an adjacent main repeater or terminal

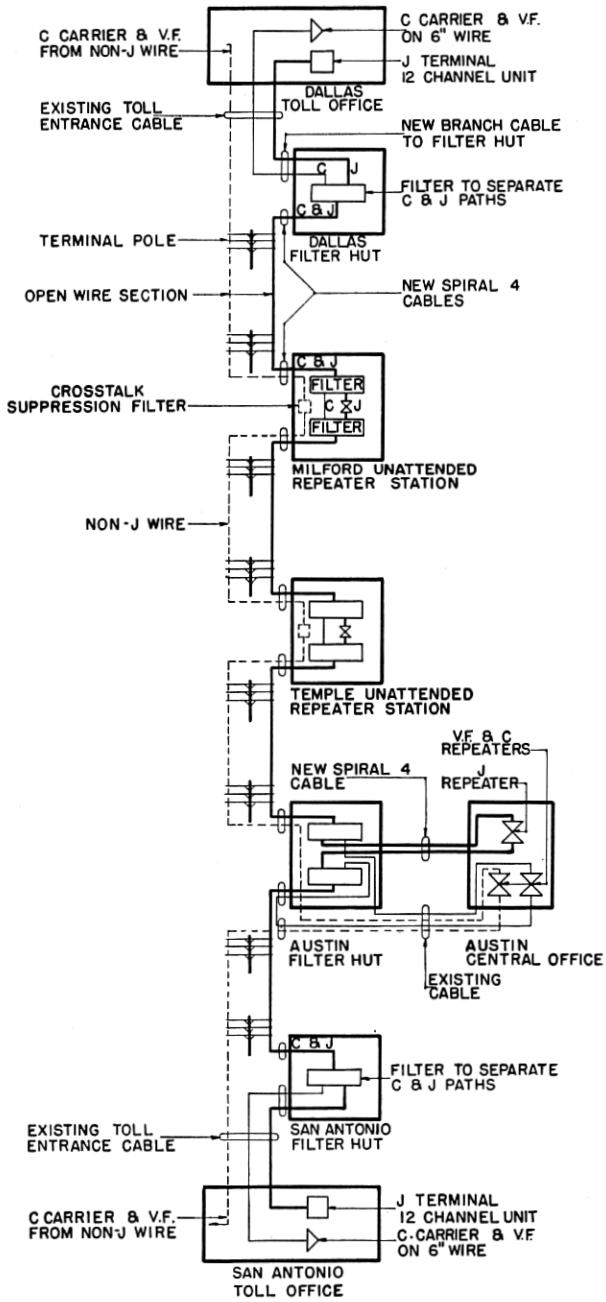

Fig. 4—Arrangement of facilities for a typical J carrier system.

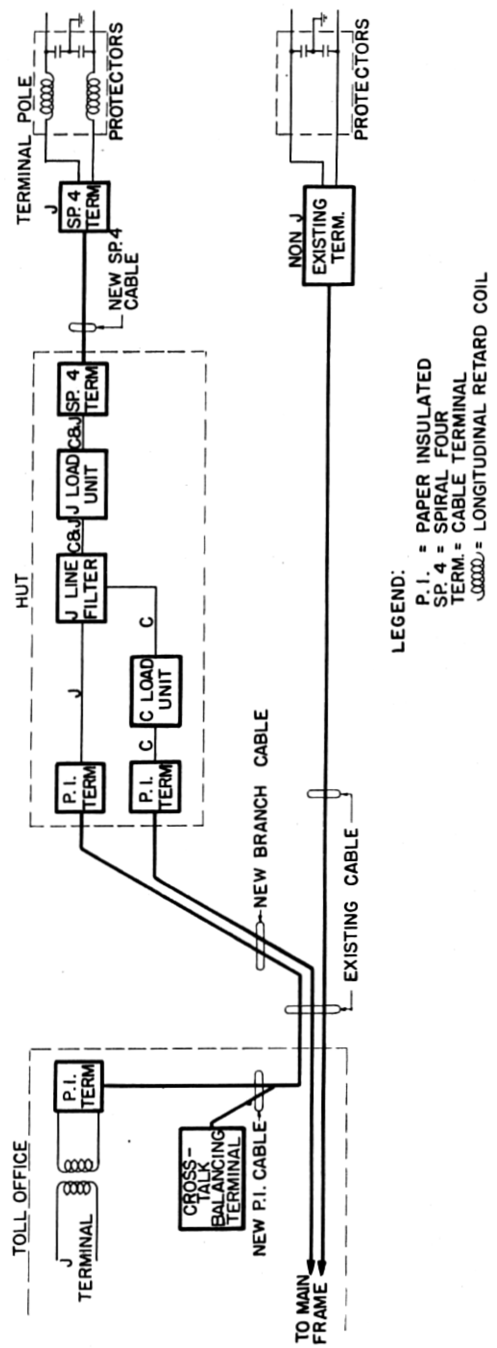

Fig. 5—Circuit connections through Dallas filter hut from open wire to terminal equipment at central office.

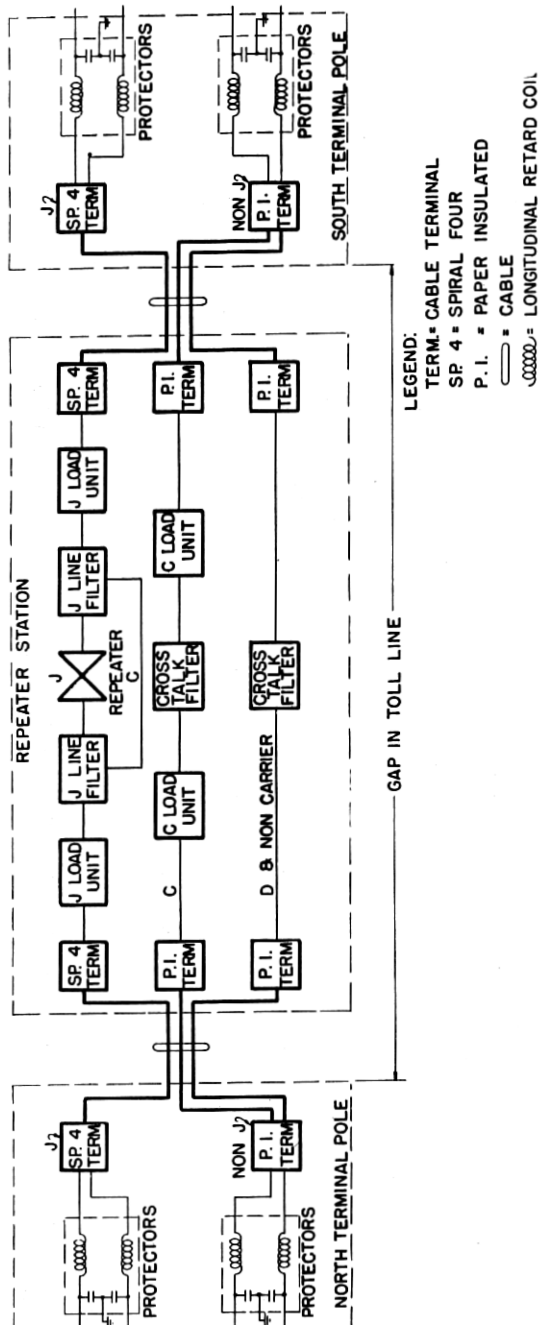

Fig. 6—Circuit connections through Temple unattended repeater station.

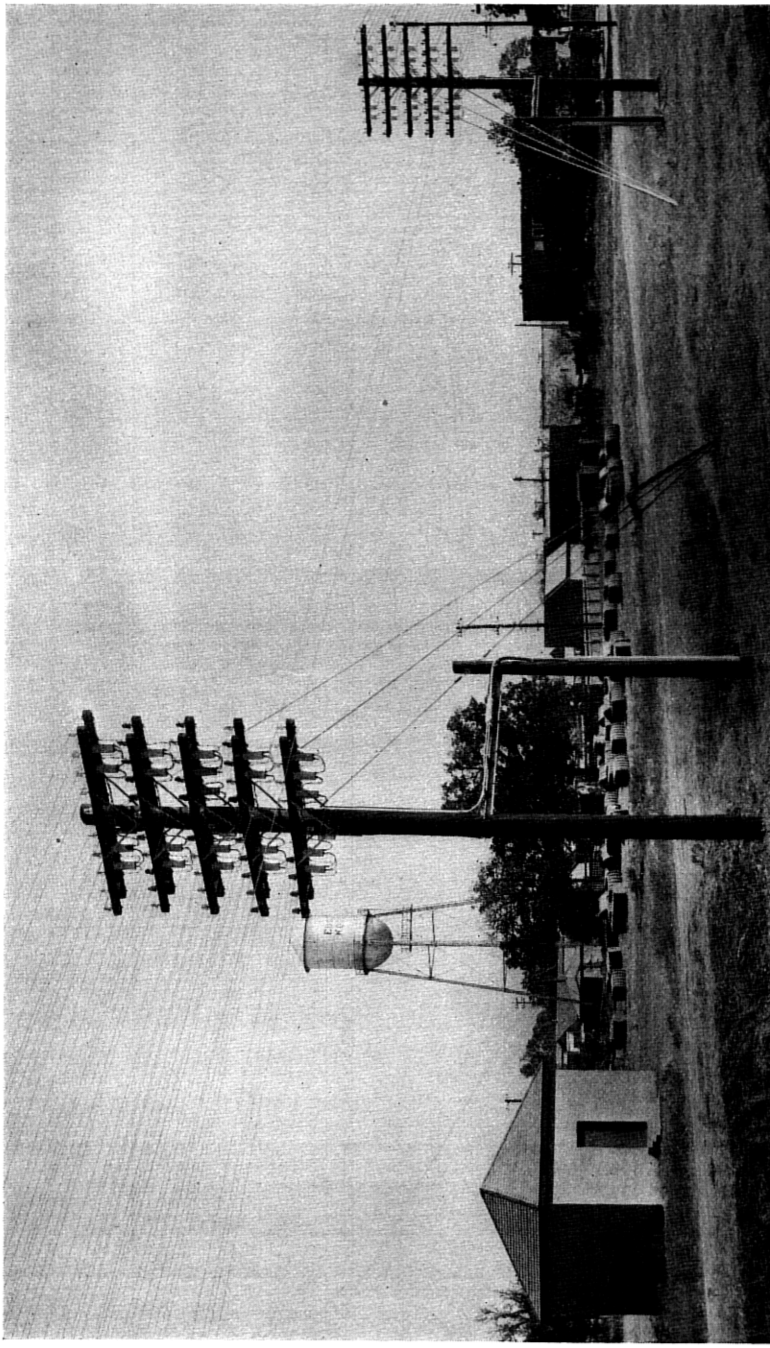

Fig. 7—Arrangement of gap in toll line at unattended repeater station.

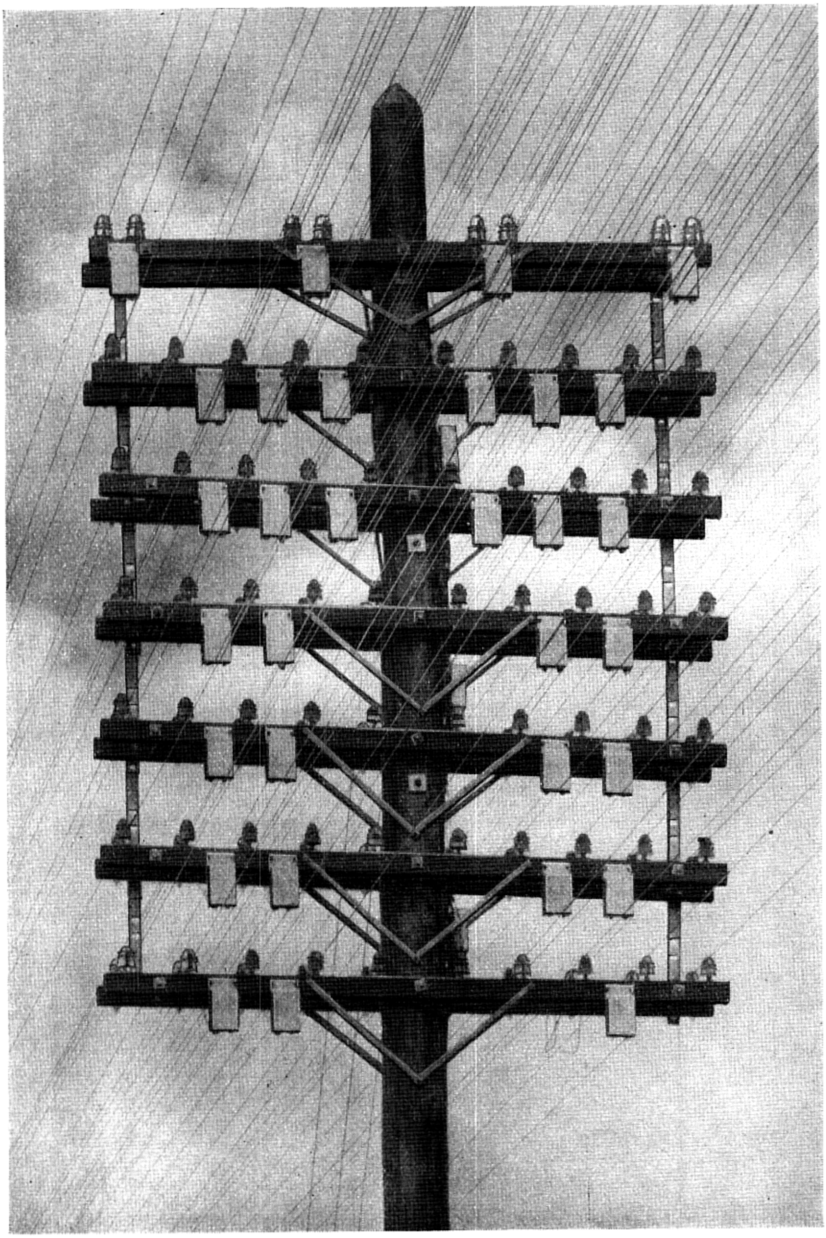

Fig. 8—Longitudinal choke coils and protectors on terminal pole at unattended repeater station.

office. This alarm has been arranged to operate by direct current over one conductor between offices without interfering with existing telephone circuits but at the expense of one DC telegraph path. For fuse failure, rectifier failure, power off, power restored, high-low voltage, high-low temperature, fire, burglary, pilot channel failure, and end of pilot channel control, alarms are sent and identified. A questionable alarm may be rechecked from the attended office.

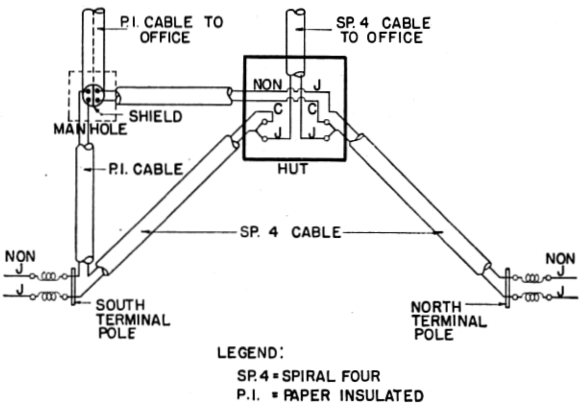

Fig. 9—Cable arrangement at Austin.

Special Problems

Some of the problems encountered in connection with the other two systems may be of interest. At Corsicana, a repeater point on the Dallas-Houston system, a filter hut was used on only one side of the repeater station. The situation which led to this arrangement is that an intermediate cable in the Dallas-Houston line extends 0.2 mile north and 0.5 mile south from the local central office. As it is necessary that the J system operate through this entrance cable and since space was available in the local central office building, repeater equipment similar to that installed in unattended buildings was placed in one room in the office.

The section of cable north of the central office terminates on a corner in a business district with all adjacent property occupied by buildings, making it more economical to use loaded spiral-four cable to this location than to extend the existing cable to an available site and provide the necessary filter hut and equipment. For the longer cable, it was more economical to provide the filter equipment in a hut in order to use existing facilities. Although this cable terminates in a fully developed residential area, a site for a filter hut was obtained adjacent to an alley in the rear of one of the residences facing the street on which the terminal pole is located.

The use of non-loaded paper insulated pairs in existing entrance cables has been mentioned. However, it is in general not practicable for crosstalk reasons to use all the non-loaded pairs which are available in one cable, and the selection of pairs suitable for type J operation is illustrated by a discussion of the methods used on the Dallas cable.

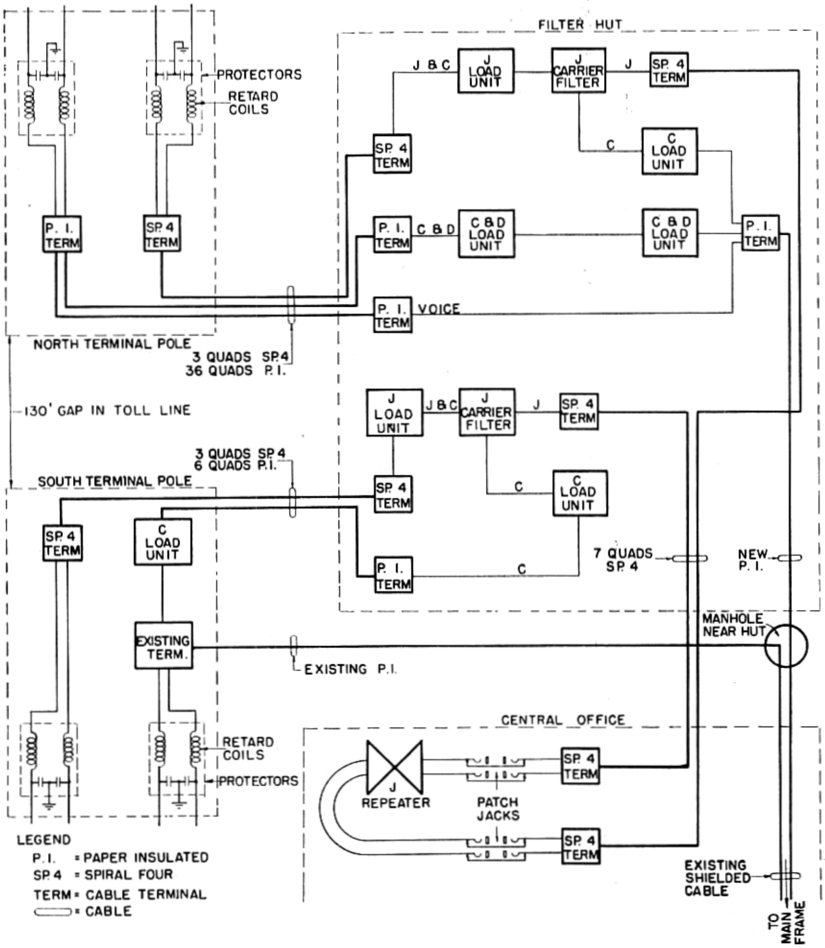

Fig. 10—Circuit connections through Austin.

The Dallas cable is composed of three sections of different make-up. The section nearest the central office, 1.3 miles long, and the intermediate section, 1.6 miles long, each contained 22 idle non-loaded pairs, and the third section, one mile long, had only six. The Houston line

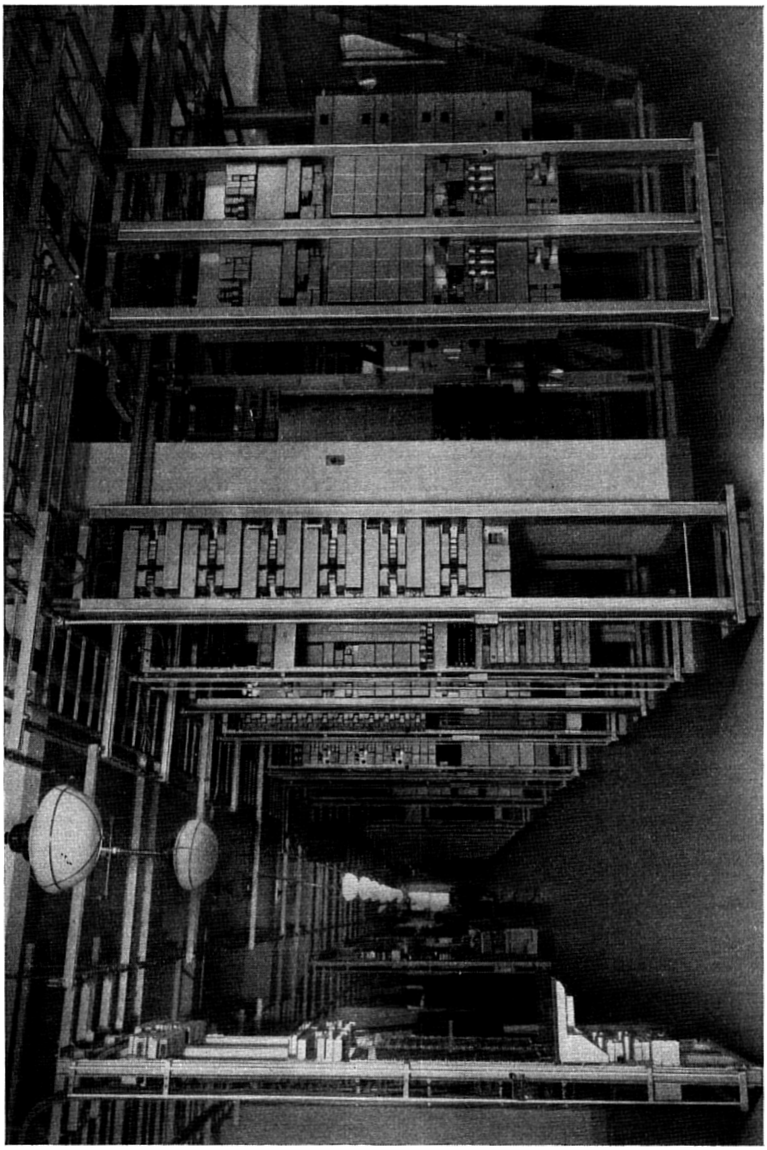

Fig. 11—Toll line terminating and testing equipment at Dallas with J carrier terminals in foreground.

terminates at the end of the second section, the third section extending the cable to the San Antonio line.

Since the number of cable pairs to the San Antonio line was limited to a maximum of six and since the rate of circuit growth over the two lines was expected to be approximately the same, requiring cable relief over the entire distance when the branch to the San Antonio line was exhausted, an objective of six pairs to each line was set up.

Measurements of crosstalk coupling at 140 kilocycles in terms of inductance and capacitance unbalance were made between each pair and all other pairs in each section and the pairs rated in their order of desirability. It is of interest that this required a total of 854 measurements. Those pair combinations whose coupling of the mutual inductance type was high were rated as the least desirable. This was done because capacitance balancing was to be used to obtain crosstalk reduction. The more desirable pairs in the first two sections were connected through to the six pairs in the last section by cut and try method until the overall condition was such that all six pairs were acceptable. By a similar procedure, using the remaining pairs in the first two sections, six pairs to the Houston line were made acceptable. No record is available as to the number of tests made in the cut and try process.

A cable terminal on which balancing condensers were mounted was installed in the central office building and connected to the selected pairs. This terminal contained sixty-six small adjustable wire wound condensers which were connected between each pair and every other pair. The condensers were adjusted to reduce to a minimum the capacitance component of the crosstalk coupling.

Buildings

For the three J carrier systems, four new repeater stations and eight filter huts were needed. The same type of construction was used for all: Concrete foundation with floor slab above grade, double four-inch brick walls with rock wool insulation between but with solid brick at corners and openings, pitched roof with wood framing, fire resistant wall board ceiling, fire resistant composition shingles, and heat insulation above ceiling and below floor slab.

All of the racks for equipment in the unattended repeater stations are arranged in three rows with power, repeater, and line equipment in separate rows within a floor space of 17 feet by 16 feet which will allow the ultimate installation of six repeaters in each building. The entrance cables from the terminal poles enter from iron conduit through the floor and are racked and spliced on the side wall adjacent to the line bays. The stubs from the cable terminals at the top of the line bays are carried overhead to splices on the wall. A ceiling height of 13 feet is maintained above the equipment but reduced along the pitch of the roof to 11 feet 8 inches at the side walls.

For all huts except that at Austin, three adjacent bays of racks are needed. With these along one side wall of the hut, the opposite side is available for splicing the entrance cable. At Austin an ultimate of

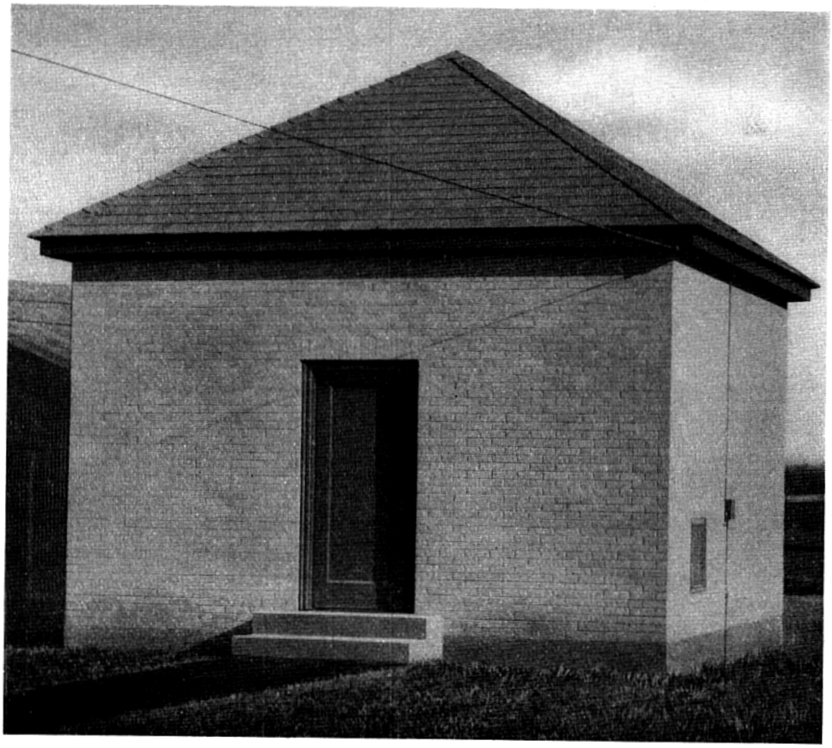

Fig. 12—Unattended repeater station.

nine racks, for filters in both directions of transmission, led to the use of racks along opposite sides of the hut with a splicing pit under the floor made accessible by trap doors in the floor between the lines of racks. In this case, the cable terminals are installed at the bottom of the racks with their stubs dropped directly through the floor slab into the splicing pit. The racks in the hut are seven feet high and a ceiling height of eight feet is used. Figures 12, 13, 14, and 15 are pictures of a typical repeater station, typical filter hut, and the special hut at Austin.

For correct operation of the equipment, temperature limits of 32 to 110 degrees Fahrenheit are desirable. Also, it is necessary that there be no precipitation of moisture on wiring or equipment. To maintain the desired conditions, each of the huts is equipped with a 2 kw. blower type electric heater arranged to operate at low temperature or high relative humidity, but with operation blocked when the temperature

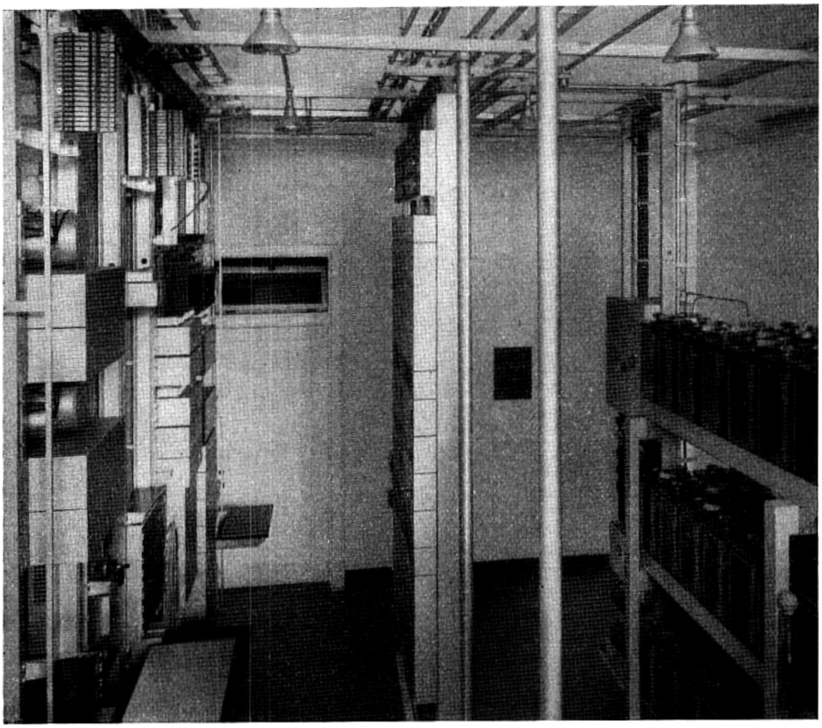

Fig. 13—Equipment in unattended repeater station.

reaches 95 degrees. Each new unattended repeater station is equipped with a 4 kw. heater similarly controlled, and, on account of the heat dissipation of power plant and vacuum tubes, also has forced ventilation which is operative under conditions of high temperature. The system of forced ventilation consists of spun glass intake filter, exhaust fan, electric solenoid controlled shutters at intake and exhaust, and thermostat, and is interconnected with the office alarms to prevent fan operation in case of fire.

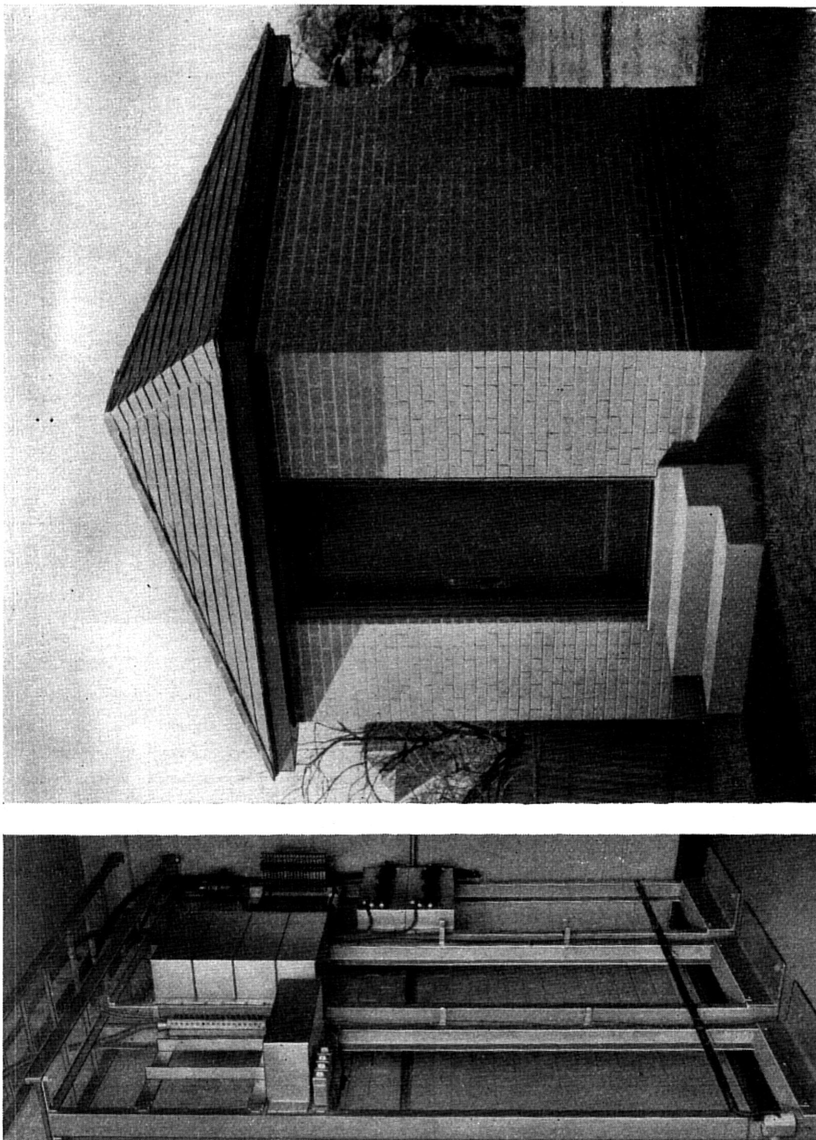

Fig. 14—Filter equipment and typical hut.

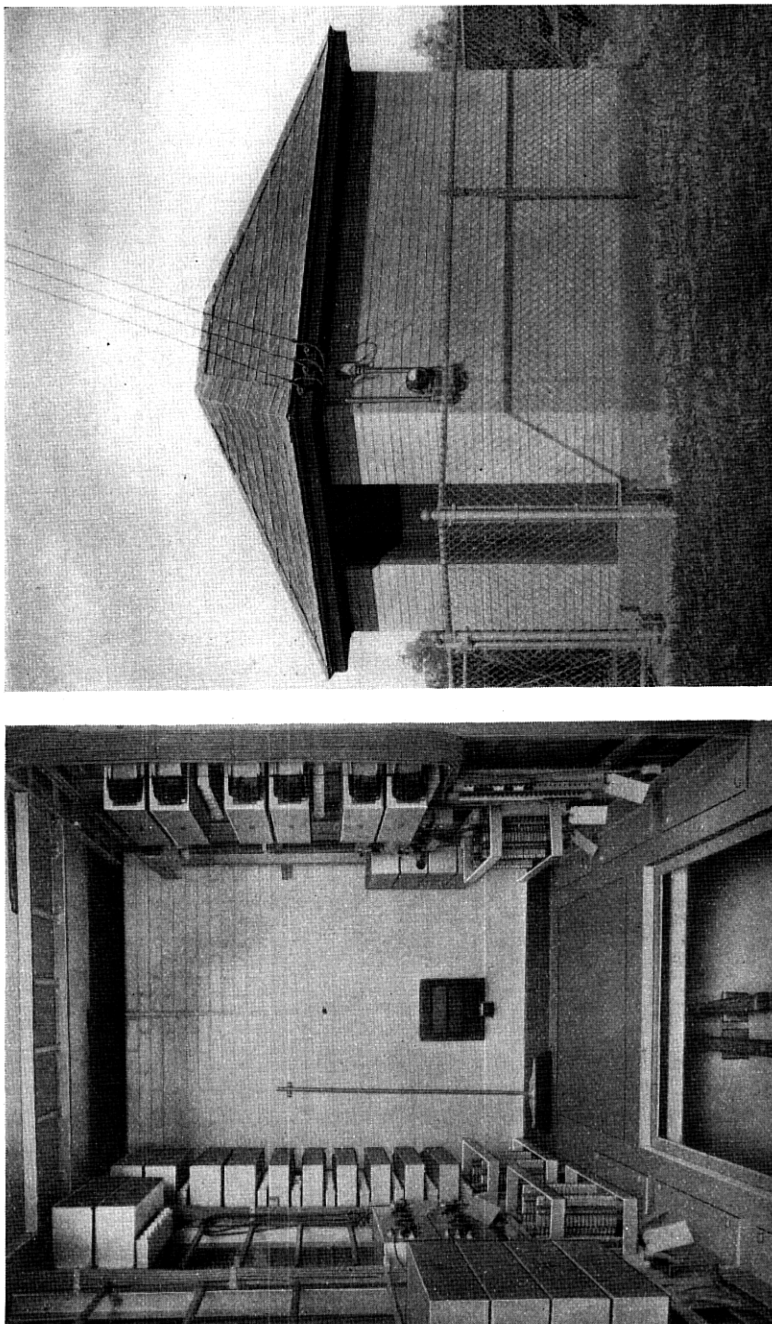

Fig. 15—Filter equipment and hut in Austin.

Conclusion

Upon completion of the buildings, equipment installation, and line facility rearrangements, adjustments in the equipment were made to match the lines used. Networks associated with the terminal and intermediate amplifiers were adjusted so that the amplification for any particular frequency would be equal to the attenuation at that frequency in the preceding repeater section; the automatic pilot channel equipment[1] compensates for attenuation changes. In repeater sections containing long toll entrance cables, it was necessary to sacrifice range of automatic pilot channel control to obtain the best equalization. However, satisfactory equalization and range of pilot channel control were obtained in every case.

As mentioned previously, the Dallas-Longview system operates on twelve-inch spaced phantomed wire. In Fig. 16 the attenuation

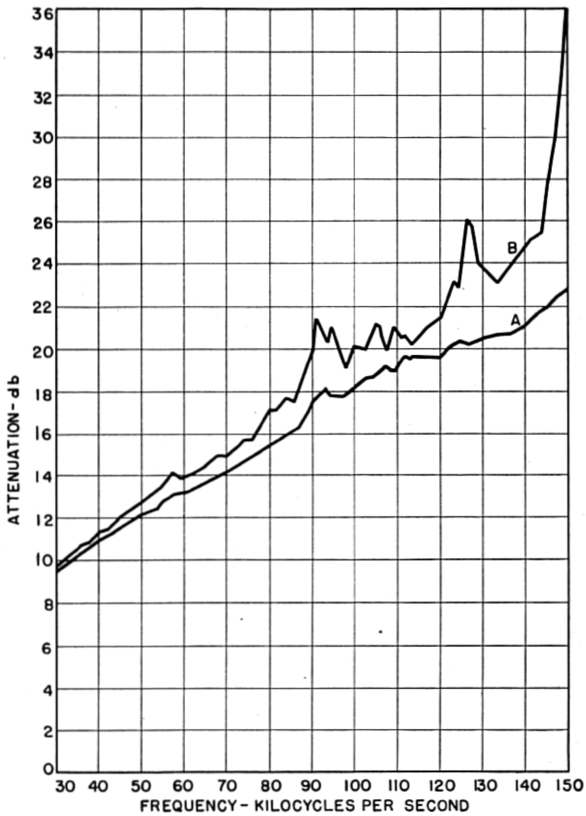

Fig. 16—Attenuation of two twelve-inch spaced phantomed pairs of the Edgewood-Longview repeater section.

[1] Loc. cit.

characteristics of two possible pairs are shown. The absorption peaks of pair "A" at 92 and 127 kilocycles are within the frequency range of channels the fourth and twelfth of the J system and would impair the quality of those channels if pair "A" were used. Therefore, pair "B" is used as the regular path for the system. The quality of the channels obtained from these systems is shown by Fig. 17. Curve

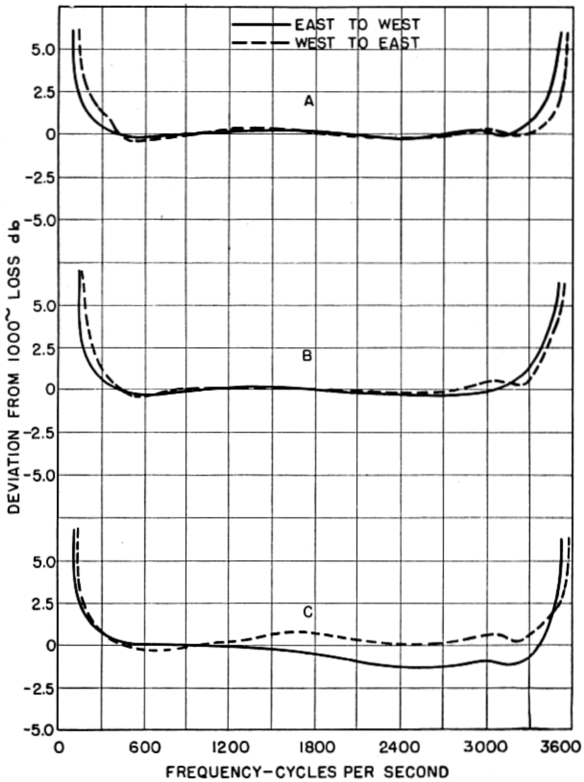

Fig. 17—Quality of derived circuits, "A" for typical channel of systems on six-inch spaced wire, "B" and "C" for the best and poorest channels of system on twelve-inch spaced wire.

"A" is representative of that obtained from a system operating over six-inch spaced wires; "B" and "C" are the best and poorest obtained from the Dallas-Longview system.

The Dallas-San Antonio, Dallas-Longview, and Dallas-Houston systems were placed in commercial service in September, October, and November, 1938, respectively. Experience with these systems is that the circuits obtained compare favorably with those obtained from any other facilities in quality and continuity of service, and that a definite need has been fulfilled in providing an economical method of increasing the capacity of the existing plant.