WESTERN UNION
Technical Review

Radio–Facsimile for Telegram Delivery

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Dial Switching Monitor

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FM Telegraph Network

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P.A. System for Switching Centers

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Radio Relay Monitor

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Presenting Developments in Record Communications and Published Primarily for Western Union's Supervisory, Maintenance and Engineering Personnel.

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Progress in Radio-Facsimile for Telegram Delivery

C. JELINEK, Jr. and K. R. JONES

PHYSICAL DELIVERY of telegrams to the occasional patron has been a problem of long standing and of major importance to the Telegraph Company, and considerable thought has been given to means by which this service can be improved. The practical extension of the radio-frequency spectrum in the last ten years to the very high frequency (VHF) band and beyond, and the increased availability after the war of commercial equipment for use in this band, made it appear desirable to experiment with the use of radio in that range for this purpose.

Suburban and rural areas are presently served by motor messengers dispatched from a main or branch telegraph office with telegrams destined for a certain general area. Usually, the time enroute to and from the delivery area amounts to a considerable portion of the messenger's tour of duty. If, for example, in 8 hours 6 runs are made and it takes 15 minutes to reach the delivery area, 15 minutes to return, park a car and report, 3 hours daily are consumed in travel time. Employing radio to transmit the telegrams directly to a motor messenger assigned to a given area may reduce this nonproductive time to a minimum of a half-hour per messenger.

In 1947 an experimental system using facsimile on a radio channel was installed at Baltimore, Md. The mobile unit, or "Telecar", see Figure 1, consisted of a 1946 Plymouth sedan equipped with two-way radio-telephone and facsimile recorder. The fixed station was located at an existing cable house at the edge of the main business district. It was remotely controlled from the central office, a distance of about two miles, where a facsimile transmitter and the radio control equipment were located. The FM radio system operated in the 152-162-megacycle VHF band and a power output of 45 watts was radiated from both the fixed station and the mobile unit. Figure 2 is a block diagram of the entire system.

Figure 1. First Western Union "Telecar"

When service trials were made it was immediately seen that average delivery time could be cut to about one-half. In addition to this distinct benefit to the public in faster service, the operation of the new system indicated a possible economic advantage to the Company. Because the return trips to main or branch offices were eliminated, and because the average distance between deliveries was decreased, the production in messages delivered per hour almost doubled. A motor messenger operating in the Telecar could now deliver with less effort as many as 70 or 80 messages in an 8-hour tour.

A paper presented before the Winter General Meeting of the American Institute of Electrical Engineers in New York, N. Y., January 1951.

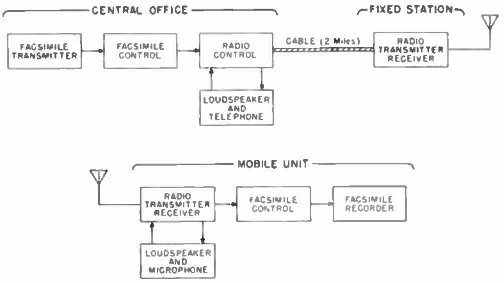

Figure 2. Block diagram of mobile radio facsimile system

In view of the promising results of this first experimental installation at Baltimore, Western Union made application to the FCC for permanent frequency assignments in the 152-162-megacycle band. After a hearing in 1948, the Commission rejected the request for frequencies in that band for this service, but assigned four frequencies between 35 and 44 megacycles for the purpose. As some increase in natural and man-made interference could be expected at this lower frequency, another series of tests were made to determine if the new frequencies were satisfactory. These tests were made under the same conditions as the original tests and with similar equipment, except that the fixed station power was increased from 45 to 250 watts.

In these later tests the new frequency and power provided satisfactory noise-free service. The service area, where the signal-to-noise ratio was at least 25 decibels, was increased from about 28 square miles with the earlier frequency and power, to about 75 square miles. Busy traffic intersections, railroad underpasses, bridges, viaducts, and similar places where there were extremely strong noise fields and/or low signal areas, were the only unsatisfactory points found.

Messages recorded by facsimile in such locations show streaks or specks, depending upon the character of the noise. In such cases, while the message may be completely readable, the motor messenger may ask for a repeat. During the service trials, the frequency of these repeats or reruns, due to noise, accounted for approximately one-fourth of a total of 4 percent reruns required. Reruns due to facsimile operation and all other causes, either at the main office or the mobile unit, accounted for the remaining 3 percent.

Mobile Equipment Arrangement

The 35-mc FM radio transmitter and receiver, complete with power supplies, was mounted in the trunk compartment of the car. A microphone was mounted on the steering post and the loud-speaker and control on the instrument panel. The facsimile recorder was installed under the right-hand side of the panel. Amplifiers and controls for the recorder were housed in a metal cabinet, mounted on a shelf behind the driver's seat. A separate storage battery of 204-ampere-hour capacity was used as a primary power source for both radio and facsimile. This battery was housed in a metal box which was bolted to the floor of the car directly in back of the driver's seat under the control cabinet. This arrangement is pictured in Figure 3.

Due to the high ampere-hour load, both sustained and intermittent, battery charging equipment of high capacity was needed. Accordingly, a Leece-Neville 3-phase alternator driven by two V-belts coupled to a double pulley on the crankshaft was used. A selenium rectifier converted the 3-phase currents to direct current and a voltage regulator auto-

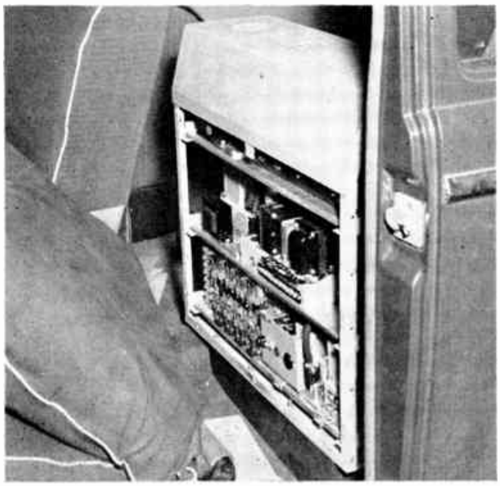

Figure 3. Control cabinet in Telecar

matically regulated the charging rate. The rectifier stacks were mounted in the space between the car radiator and grille for maximum cooling. A charge rate meter installed on the instrument panel completed the charging system. Charging rates varied from 25 to 35 amperes at idling speed and up to 80-90 amperes at operating speeds.

The location of the antenna was an important factor in the installation. In order to obtain the best efficiency, the antenna was mounted as high as practical on the metal body of the car, also as clear as possible of paralleling sides of the body. While the length of the antenna is not critical, it was cut to be close to 1/4 wavelength of the operating frequency for best results.

Initially, for motor noise suppression, resistance-type suppressors were used. It was found, however, that at remote distances from the regularly assigned area, where the signals were very weak, the remaining interference was sufficient to print on the received copy. The suppressors were then replaced by a complete shielding of the entire ignition system and this corrected the trouble.

Mobile Radio

The mobile FM receiver was a crystal-controlled, single-frequency, double superheterodyne unit. It was designed particularly for mobile service and afforded adequate selectivity and sensitivity. The audio channel delivered an output of four watts, with 10-percent maximum distortion, into a 500-ohm line. A vibrator or dynamotor power supply furnished the required "B" voltage. Both types were tested in service with equally good results.

The mobile FM radio transmitter was crystal-controlled and capable of a power output of 45 watts at the assigned frequency. The plate voltage necessary for operation was obtained from a dynamotor. In view of the large primary currents, a dynamotor was preferred to a vibrator-type supply. The transmitter utilized the phase-shift method of obtaining the desired frequency deviation of plus and minus 15 kilocycles. Stability of the center-frequency was held to within plus or minus 0.002 percent.

Excessive deviation of the carrier due to changing speech levels was prevented by special design of the audio input channel. Metering jacks were provided in the grid circuit of each stage and, in addition, in the plate circuits of the power amplifiers. The radio-frequency output was connected to the transmission line through the contacts of a coaxial relay. A relay, energized by the facsimile recorder, disabled the mobile transmitter while a facsimile message was being received. This prevented an interruption if the transmitter were inadvertently operated.

In actual service, when the central office had a choice of telegrams to send or a dispatching question, an immediate answer from the car was desired. Originally, if the car was moving in traffic, the answer had to be deferred until the vehicle was pulled off the road and stopped to enable the driver to free his hands to pick up a telephone handset. To eliminate this delay, a small push button was installed on the left-hand spoke of the steering wheel, near the rim and within reach of the driver's thumb with the hand in normal driving position, and the microphone was spring-mounted on the steering post within range of the driver's voice. The push button actuated the mobile transmitter and permitted the driver to talk to the central office while operating the car. A concealed loud-speaker in the instrument panel completed the two-way voice channel.

For night service a conveniently located reading light was provided to facilitate reading of addresses and delivery reports.

Mobile Facsimile

The mobile facsimile equipment consisted of several separate units connected in such a way that their operation was completely automatic. The metal cabinet behind the driver's seat housed all of the units except the recorder. A wiring duct in this box contained all of the interwiring, and sockets were provided at proper points in this duct so that each unit could be plugged in, or replaced easily.

The facsimile recorder shown in Figures 4 and 5 is a completely automatic recorder of the internal recording type, i.e., the recording paper is wrapped into a cylindrical form and the stylus rotates inside the cylinder to record. After feeding through the length of the cylinder and recording the entire message, the stylus carriage returns and the recorder then unwraps the paper cylinder. Pressure rollers are applied to feed the recorded message out over a knife edge where it is cut off and dropped into a receptacle.

Figure 4. Facsimile recorder as installed in Telecar

The block diagram of Figure 6 shows the recorder and auxiliary units connected. Although there appear to be seven units, besides the recorder, in actual practice the car selecting circuits, the frequency standard and amplifier, and the recording amplifier are all mounted on one chassis.

The selecting system was designed for three cars, since experience in the field trial indicated that this was the maximum number that could be operated from one radio channel. For example, the transmission of each message takes approximately 65 seconds, 10 messages each for 3 cars adds up to about 33 minutes, which leaves 27 minutes out of any one hour for voice communications. This is little enough time for proper dispatching and for receiving answers to messages from the mobile units.

The selecting unit consisted of a simple series-tuned audio coil and a 3-position switch which connected one of three tuning capacitors in series with the coil. The output of the tuned circuit connected to a vacuum tube-controlled relay and the closing of this relay started the recording cycle of the equipment in the car. The frequencies to which the circuit responded (depending on switch position) were approximately 1000, 2000 and 3000 cycles. A time constant in the relay circuit prevented the starting up of the equipment unless the selecting tone was held for a duration of 1 to 2 seconds. This prevented false operation by spurious signals or voice. The selecting tone originated at the main office and its duration was controlled there by an automatic timer.

A requirement for facsimile operation is that the transmitter and recorder rotate synchronously, with an accuracy of at least one part in about fifty thousand. The most practical way to accomplish this

Figure 5. Facsimile recorder with cover removed

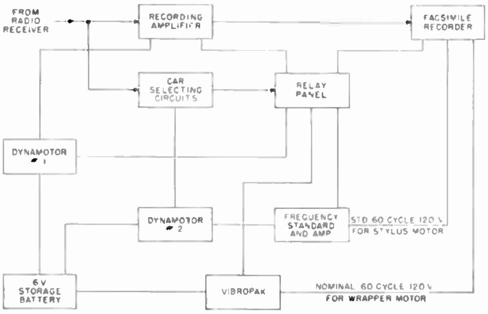

Figure 6. Block diagram of recorder and auxiliary units

was to use a synchronous motor to drive the recorder stylus, the motor in turn being driven from a frequency standard. Accordingly, a small fork-type frequency standard with output frequency of 240 cycles was used. This was divided by a synchronized relaxation oscillator to give an output frequency of 60 cycles. Push-pull output tubes were used to amplify this 60-cycle voltage to approximately 15 watts which was used to drive the stylus motor. Of course, the drum of the central office transmitter was synchronously driven from a similar source of constant frequency.

Mobile Power Requirements

As was mentioned earlier, the current drain on the storage battery, both sustained and intermittent, was high. In fact, in the first experimental equipment the facsimile load in stand-by condition was 20 amperes and when recording about 40 amperes. Now, since the recording time is around one minute, and since about ten messages per hour are recorded because that is all the messenger can handle, it is obvious that the 40-ampere recording load is not as important as the 20-ampere stand-by load. In any one hour, under these conditions, 400 ampere-minutes would be drained by the ten messages recorded. The 20-ampere stand-by load, however, would account for 50 times 20 or 1000 ampere-minutes.

The radio equipment available in the early days of this experiment also used about 20 amperes in the stand-by condition. Therefore, some method of reducing this steady drain on the storage battery was required, from the standpoint of battery life and charging rates to be maintained.

It was found possible to modify the experimental equipment so as to reduce considerably the facsimile stand-by load. By using the new quick-heating filamentary tubes that became available, and by modifying the relay circuits so that these tubes as well as the dynamotors for "B" voltage supply could be turned on for recording and off when idle, several amperes of stand-by current were saved. The stand-by condition of the equipment thus required less than 10 amperes, with the circuits being energized as follows:

1. Car-selecting tube filament heated;
2. Fork-frequency standard energized and 60-cycle frequency amplifier tubes lighted;
3. "B" voltage supply dynamotor for the above two units (No. 2 in Figure 6) running at reduced speed.

Mobile System Operation

A brief explanation of the control signals and the tracing of these as well as message signals through the mobile system (Figure 6) will help in understanding its operation. Each message transmission is preceded by a period of 5 to 7 seconds during which control signals are sent as follows:

1. A 1- or 2-second steady tone for selecting the car. This is an audio tone of 1000, 2000 or 3000 cycles generated by an oscillator at the central office.
2. A 2-second interval of silence for wrapping of paper and readying of the recorder.
3. Two or three seconds for transmission of phasing pulses.

Referring to Figure 6 and keeping in mind the circuits that are in the stand-by condition, note how the equipment responds to these signals. The audio signals coming from the radio receiver take two paths, one to the recording amplifier and one to the car selecting unit. Since the recording amplifier "B" voltage is not on, the 2-second steady tone energizes only the car selecting unit, causing a line relay to pull up and charge an RC circuit. At the end of the 2-second interval the line relay releases, discharging this capacitor into a power relay winding. The power relay contacts turn on all the other equipment. The 2-second interval of silence allows the recording amplifier tubes to heat and both dynamotors as well as the recorder power and stylus motors to come up to speed. The recorder mechanism wraps and the stylus is ready to traverse the message blank to record.

At the end of the silent interval, phasing signals begin. These are short pulses of selecting tone which are derived at the main office from a commutator on the transmitting drum shaft. Ten or 15 pulses are sent so as to provide a factor of safety since the car may be passing under a bridge or viaduct where, momentarily, phasing signals may not be received.

The line relay responds to these signal pulses, and again charges the RC circuit. This time, however, the discharge path is through a phasing relay winding which releases the stylus shaft and allows recording to take place.

The transmitter and recorder line feeds are arranged so that the main office transmitter completes scanning just before the recorder, and no end-of-message signals are required. The recorder end-of-message switch actuates the feed-out and cutoff mechanism and when this action is completed the original stand-by condition is restored.

Fixed Radio Station Details

The cable house mentioned previously was an excellent spot for the experimental station. It provided all necessary facilities including cable pairs to the central office. The antenna was a vertical coaxial dipole, mounted atop an 85-foot wooden pole, suitably guyed. A messenger wire supported 1-inch tubing in which RG/8U coaxial cable extended from the hut to the antenna. Two No. 9 wires grounded the antenna skirt for lightning protection. All the fixed station equipment was rack mounted, and was entirely self-contained within a single 7-foot steel cabinet.

As in the mobile unit, the FM transmitter here also utilized the phase-shift method of obtaining the desired deviation of plus and minus 15 kilocycles in its operating range of 30 to 50 megacycles. This permitted direct crystal control of the carrier frequency and a stability of plus or minus 0.002 percent. Frequency generation, modulation and the necessary frequency multiplication were accomplished in an exciter unit with an output of 50 watts at the carrier frequency. This power was raised to the 250-watt level by a power amplifier tuned to the same frequency. Power for the amplifier was derived from a single-phase full-wave rectifier rated at 2000 volts at 300 milliamperes. Interlocking door switches shut off this high voltage, for the safety of maintenance personnel. The radio-frequency output was connected to the transmission line through the contacts of the antenna transfer relay.

The station FM receiver was similar in design to the mobile receiver, differing mainly in the type of power supply, and in that the station receiver was rack mounted. The station receiver contained a built-in a-c power supply. Its audio output was always connected to a station loud-speaker and, in addition, to a line terminal panel where connections were made to the cable pairs from the central office.

Central Office Radio Equipment

The radio installation at the Baltimore main office consisted of a remote control amplifier and loud-speaker, telephone handset, telephone headset, and a monitor radio receiver. The remote control amplifier provided d-c relay current and necessary two-way audio amplification. An automatic compressor circuit maintained the voice level going to the line at a constant value for input variations of plus or minus 10 decibels. Incorporated in the amplifier was a decibel meter providing the operator a visual indication of normal levels. The meter was also essential to maintenance personnel for setting the facsimile black and white levels. When the headset was used, a foot-operated switch controlled the radio transmitter to free the operator's hands for transcribing a message from the Telecar. The monitor radio receiver was similar in design and construction to the fixed station radio receiver. However, a meter was added to observe the strength of the fixed station radio signals, and "carrier on and off" indication. A loud-speaker operating at a reduced level monitored the modulation of the radio transmitter.

Frequency modulation was used in this application as high-fidelity transmission and freedom from interference is required. In this system the dynamic response of the over-all FM radio system is linear over a 25-decibel range. This insures that facsimile transmission will not be impaired by the radio link. Non-linearity occurring anywhere in the system will be apparent in either "fill-ins" of vertical lines close to one another, or "drop-outs" of faint lines on the subject copy transmitted.

In order to preserve system linearity and the normal 25-decibel signal-to-noise ratios, as well as to comply with the FCC Rules and Regulations, the following procedure was used to set the FM deviation. A steady-state 2400-cycle carrier frequency was obtained from the facsimile unit at the main office. Its amplitude corresponded to full black from the message blanks, when seen by the photocell and its associated amplifiers. The radio transmitter modulation control was then used to set the bandwidth of the transmission to be 80 percent of the allowable bandwidth. An accurately calibrated frequency monitor was employed to determine the extent of the frequency deviation due to modulation. When the steady-state test tone was replaced by the interrupted carrier, two side frequencies of approximately 400 and 4400 cps were developed and modulated the transmitter. This caused the percentage of used bandwidth to rise to approximately 90 percent in traffic conditions. The remaining 10 percent was a safety factor to prevent overmodulation, due to power-line surges, changing line losses or facsimile output fluctuations. This also permitted a possible small variation in the center-frequency of the radio transmitter to be tolerated.

Central Office Facsimile Equipment

The original installation at the Baltimore main office consisted of a "card-type" transmitter and its associated equipment, i.e., converter, frequency standard, control circuits and so forth.

The card-type transmitter was designed to transmit from small message blanks about 3 inches by 5 inches in size, and was built originally to work with the card recorder used in the mobile unit. This transmitter rotated at a speed of 300 rpm and the elemental area scanned (aperture size) was 0.010 inch. With a line feed of 100 lines per inch, the 3-inch dimension was completely scanned in 1 minute. With an aperture size of 0.010 inch and a linear speed of 25 inches per second, the modulating frequency developed was 100/2 times 25 or 1250 cycles per second. This modulation frequency was caused to amplitude modulate a 2500-cycle carrier which was put on the line to the radio transmitter. While this original equipment gave very satisfactory results it was deemed to be uneconomical since each message had to be recopied onto the small blank so it could be transmitted.

Early in 1948, the vertical drum scanner[1] was developed and since this machine took the regular size Western Union message blank a modified version was installed in the Baltimore system. Although this eliminated the necessity of recopying each message, several other economic factors were brought into importance.

First, scanning the large message blank at 300 rpm generates a modulation frequency of 2000 cycles per second (the linear speed being 40 inches per second), and to faithfully reproduce this modulation at the facsimile recorder a carrier frequency of at least twice that of the modulation is usually required. If the facsimile carrier frequency is increased and used to phase-modulate a radio carrier frequency, the effect is to increase greatly the deviation of the radio carrier. Since the total deviation is limited by FCC regulations, it would be necessary to decrease the amplitude of modulation in order to maintain the same radio bandwidth as was had with the low facsimile carrier frequency. Experimentally this proved to be a decrease of about 12 db, the factor by which the signal-to-noise ratio was reduced. It can be seen, therefore, that more radio transmitters or at least transmitters of higher power would have to be used to get the same radio coverage as was previously had.

The use of a lower drum speed which would produce lower modulating frequencies and therefore permit lower carrier frequencies could not be tolerated. The time of message transmission could not be greater than one minute in order to utilize each radio channel economically, i.e., serve three cars.

This, then, was the situation early in 1949. At that time, members of Western Union's Transmission Research Division proposed a scheme which would effectively reduce the facsimile carrier frequency while retaining fidelity of modulation envelope. This was a method of double modulation which provided a facsimile carrier only 300 cycles higher than the modulation frequency itself. At the recorder, a carrier frequency-doubler is used to double the number of recording pulses per signal envelope. Thus the over-all facsimile definition is maintained and the radio bandwidth is not increased.

A simplified version of this scheme uses a chopper disk in the facsimile transmitter which provides a carrier frequency high enough so that the derived modulation envelope is of high fidelity. This is fed into a Western Union Type 22 Regulator-Inverter where the modulation is detected and a balanced modulator is used to modulate a lower frequency carrier which is then put on the line to the radio transmitter. Accordingly, this simplified version of double modulation was installed at the main office in Baltimore.

Delivery Trials

Live traffic tests with the one mobile unit were conducted for a period of more than three months. The delivery area chosen was a 70-square-mile section of North Baltimore which consisted mostly of residential and small business districts.

The operating routine was as follows: When the Telecar left the downtown garage its operator would call the main office via radio to notify the dispatcher that he was on his way to the delivery area. The dispatcher would acknowledge and then send a facsimile test message. This test served as a check on the over-all system, i.e., recording and transmitting levels and so forth. Upon receipt of the test message the Telecar operator would announce his location and ask for the address of the first delivery. Many times the first delivery was within two or three blocks of the Telecar's announced location. The routing of regular messages from then on was such as to minimize the distance that the car would have to travel to effect delivery.

During the 3-month trial period there were many instances of message deliveries within two or three minutes after their arrival at the main office; in fact, in one instance a message was delivered to a suburban home in North Baltimore, three miles from the nearest branch office, 17 minutes after it had been filed at a branch office in a distant city.

A tabulation of messages delivered, miles covered and other pertinent data for a 1-month period is made in Table I. There is a column listing equipment failures and circuit time outage. The cause of the failures is, in most cases, self-explanatory, but in the case of the heavy rain causing a stylus short, it should be mentioned that on the day previous a baseball had cracked one corner of the windshield, causing a leak. The tabulation shows 1622 messages delivered in 23 working days. This is an average of more than 70 per 8-hour day, or one every 7 minutes.

TABLE I

Delivery Trials

Date	*Hours*	*No. of Msgs.*	*Miles*	*Reruns*	*Time Out*	*Cause*
10/1	8	84	70	1	10 mins.	Facsimile transmitter exciter lamp failure
10/2	8¾	73	69	2	——	——
10/3	8	77	76	—	1 hour	Fixed station rectifier tube failure
10/6	8½	76	73	3	——	——
10/7	8¼	92	77	1	13 mins.	Flat tire
10/8	8¼	78	65	1	——	——
10/9	8¼	66	63	—	——	——
10/10	8	73	70	3	——	——
10/13	8¼	60	61	—	1 hour	Speedometer repair
10/14	8¼	70	72	1	——	——
10/15	8	64	70	4	15 mins.	Demonstrating equipment to visitors
10/16	8¼	63	65	4	26 mins.	Paper jam on facsimile recorder
10/17	8	62	68	3	——	——
10/20	8¼	61	59	—	40 mins.	Main office relay contact dirty
10/21	8	65	67	1	——	——
10/22	8	76	82	1	——	——
10/23	8	66	75	4	——	——
10/24	8	73	82	1	——	——
10/27	8½	72	73	1	——	——
10/28	8¼	53	70	1	13 mins.	Extremely heavy rain caused stylus short
10/29	8	66	72	—	——	——
10/30	8	86	80	1	——	——
10/31	8	66	71	3	——	——

Conclusion

In view of the encouraging results obtained from the 1-car experiment, the Company decided to expand the system to city-wide Telecar service for Baltimore. A study of the existing traffic load in the suburban areas indicated that a fleet of seven Telecars is required to provide the necessary service. One additional Telecar completely equipped is to be used in emergencies and for maintenance purposes. These cars have been provided and four fixed radio stations have been erected. Some overlapping of the service areas of the four stations is provided for, so that effective coverage of the entire metropolitan area can be maintained under practically all conditions.

After a reasonable period of operation to evaluate the results of such city-wide service, consideration is expected to be given to the extension of this type of service to other large metropolitan areas throughout the country.

A subsequent TECHNICAL REVIEW article will describe the operation of the Telecar system in Baltimore.

Reference

1. A Vertical Drum Telefax Transmitter, J. H. Hackenberg, *Western Union Technical Review*, Vol. 4, No. 1, January 1950.

THE AUTHOR: C. Jelinek, Jr., of the Telefax Research Division, obtained his education in communications engineering at the Newark College of Engineering, Columbia and New York University. Prior to coming to the Telegraph Company in 1946, he had served as Electronic Technicians Mate in the U. S. Navy, and had gained valuable experience in facsimile development with Finch Telecommunications and the Federal Telephone and Radio Corporation. His work with the Telefax Research group has been concerned with the development of facsimile apparatus of all kinds. Mr. Jelinek has been closely associated with the Telecar development described in this paper, and has contributed much towards the development of the mobile and central office Telefax equipment, and towards the ultimate success of the system.

THE AUTHOR: K. R. Jones joined the Radio Research Division of the Telegraph Company in 1945, after serving for three years with the U. S. Army Signal Corps, through whose Plant Engineering Agency he received specialized training in communications engineering. Since coming with Western Union he has been engaged in the design and development of microwave equipment and circuits, including automatic frequency control circuits for short range transmitters, and a stabilized wideband FM modulator. Mr. Jones aided in the radio engineering for the Western Union Ship Reporting Service in New York Harbor, and was responsible for the installation of experimental radio stations in Baltimore, in connection with the Telecar system described in the above article.

Dial Switching Monitor for Teleprinter Circuits

F. L. CURRIE and A. F. CONNERY

THIS ARTICLE deals briefly with the continuous need for telegraph operation supervision, and describes the monitorial arrangement designed for service at the new area reperforator switching centers of the Western Union system.

General

Where so many people of different characteristics and temperaments, and so much intricate equipment and electrical circuit networks are involved, as in the telegraph industry, continuous observation of their performance is necessary to insure that all elements are functioning properly and harmoniously in a smooth, efficient, and coordinated manner.

Even though the personnel is selected with care and consequently constitutes an efficient staff, humanity being inherently fallible, errors must be expected occasionally. That truism was well expressed by the English poet Alexander Pope when he wrote "to err is human" in his philosophical poem, Essay on Criticism. Also, the equipment and electrical circuits, while carefully contrived and maintained are, like all human creations, fallible and subject to occasional failures.

In the telegraph industry, whose business is a precise and rush form of service to the public, accuracy, speed and dependability are cardinal qualities. Those qualities must be scrupulously maintained and must never be made subjects for compromise, so that in the minds of the public the word "TELEGRAM" will always be synonymous with accuracy, speed and dependability. That is the kind of service the public has a right to expect and the kind the Telegraph Company is endeavoring to furnish. Consequently, a policy of adequate monitorial supervision of the service is necessary for the well-being of the industry.

While monitorial work is performed to some degree throughout the organization, it principally is a function of the Operating and Accounting Departments which maintain regularly constituted staffs for that purpose. The Operating Department observes the accuracy and general proficiency of the operators, the speed of service, and the transmission quality of equipment and circuit operations. The Accounting Department observes the accuracy of revenue collections and the proper accounting of those collections with especial attention given to the received collect messages.

A review of past monitorial practices reveals that, of the various methods used in this work, the more common have consisted of visual examination of the message copies themselves; of comparing the original message copy with the relay or with the final copy; and of making special recordings of the messages from the actual line transmission signals.

The special recordings, generally, were made by means of multipen direct writers or dictaphones for Morse circuits, and by means of teleprinters, similar to those normally used for message reception on the circuits involved, for teleprinter circuits. Those recording instruments sometimes were connected in series with the circuits to be monitored through jacks and plugs at the main switchboard of the office, and at other times were actuated by signals from the contacts of relays which, usually, were connected in series with the lines through jacks and plugs of the main switchboard.

While the making of special recordings of the message transmission from the actual line transmission generally was found to be the most satisfactory of those methods, the connecting of a teleprinter magnet or a relay coil directly in series with a working circuit impaired the circuit transmission to some extent. This was an undesirable condition, particularly when two or more concurrent monitorial connections were made to a circuit.

Later, that fault was largely overcome by the use of an electronic relay for repeating the line circuit signals to the monitorial circuit. That device was actuated by the voltage variation across a series resistor connected permanently in series with the line circuit, and when connected to a line circuit caused no perceptible impairment of the circuit transmission.

Enlarged Supervisory Scope

With the integration of the new area reperforator switching relay centers into the Western Union system in recent years, control of a much larger portion of the operating personnel and telegraph facilities was concentrated at single points than ever before. That condition so augmented the supervisory work at those points that a more advantageous and more efficient monitorial arrangement for supervising message transmission and equipment performance became highly desirable. Accordingly, the arrangement described in this article was designed for service at those points.

New Monitorial Facility

The new monitorial arrangement was designed to include the advantages afforded by the electronic relay, and to permit remotely establishing connections to line circuits by a selective switching means controlled by a dial mechanism in the monitorial room. The latter feature provides an economical means for effecting connections to line wires even though the monitorial room is located some distance, possibly in another building, from the point where the connections are made. The new facility effects economies in time and labor by eliminating the need for requesting a switchboard attendant, via telephone or otherwise, to connect the monitorial sets to desired line circuits or to change their connections from one line circuit to another, and it also eliminates identification of the circuits to be monitored. Hence, a monitorial supervisor, even though some distance from the switching point, is able to shift her monitorial teleprinter from one circuit to another at will without disclosing the identity of the individuals and circuits to be observed.

Equipment

As outlined in Figure 1, each monitorial set consists essentially of a dialing mechanism and a teleprinter located in the monitorial room, and of an electronic relay and a group of switching apparatus usually located in the T. and R. (Testing and Regulating) room. Accessible for connection with the monitorial sets and also located in the T. and R. room are groups of 100-ohm resistors, one of which is permanently connected in series with each line circuit made available for monitoring purposes.

Each monitorial set is associated with a specific group of 100 line circuits and is capable of being switched to any one of them. As many monitorial sets as may be considered necessary for an installation may be provided for any group of 100 line circuits. Where more than 100 line circuits are involved, an additional group of monitorial sets must be furnished for each group of 100 line circuits, or fraction thereof.

The dialing mechanism is quite similar to that ordinarily used for dial telephones and serves to actuate a set of individual but remotely located selector switching equipment.

Each set of selector switching equipment consists essentially of a 50-point, 5-level rotary switch and five control relays. Actually, the relay control circuits are arranged to cause the switch to serve as a 100-point, 3-level rotary switch, and for reasons of simplicity it will be considered as such in this description. The connections from the line circuit series resistors, two for each line resistor, are terminated at corresponding contacts of the first two levels of the rotary switch, thus accommodating 100 line circuits. The third level is used for self-stepping the

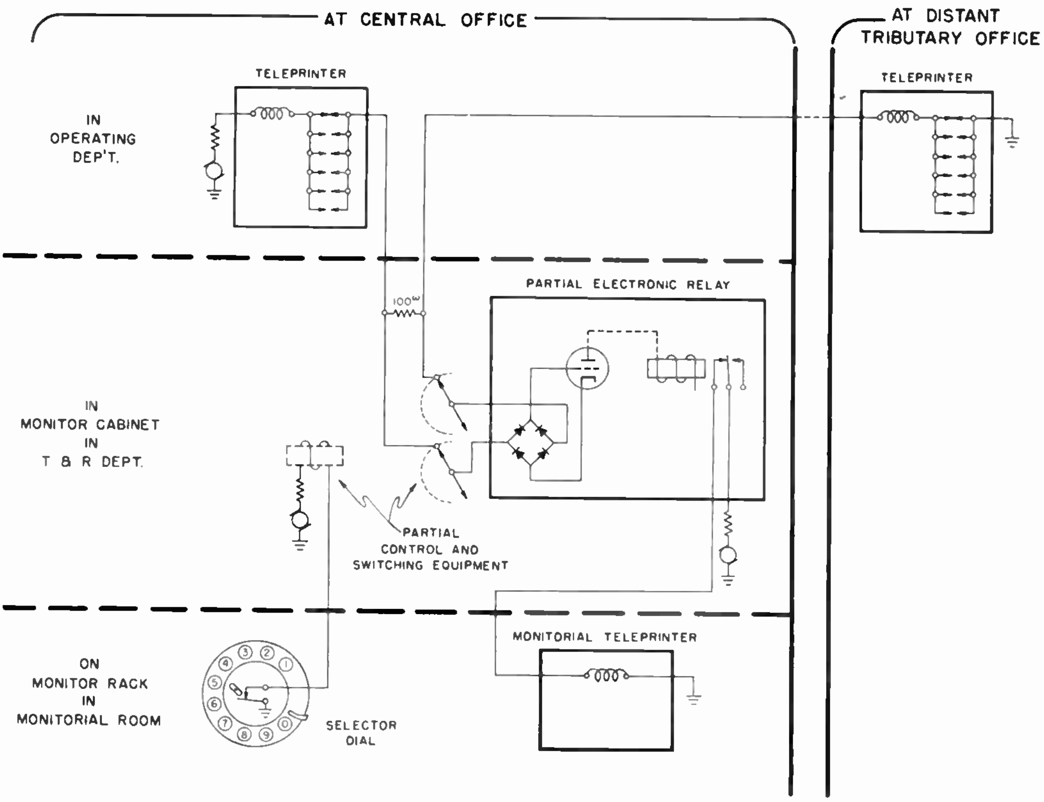

Figure 1. General outline of dial switching monitorial arrangement

wiper contacts to their home position at the conclusion of a monitorial observation.

Operation

The circuit theory for effecting the selection of, and connection to, the different teleprinter circuits is illustrated by Figure 2 which shows the equipment and circuits in their normal idle condition. Only four of the five control relays are shown in this sketch.

The switching of a monitorial set to a desired line circuit is initiated by the operation of the key switch *A* to its closed position, which starts the associated teleprinter motor running and, if the rotary switch wipers are resting at their home position, causes the control relays *IR*, *SR*, *PR* and *HR* to operate. The operation of those relays connects the two input leads of the electronic relay to the wiper connections of the rotary switch first two levels, lights the ready lamp at the respective monitorial position in the monitorial room, and makes the rotary switch stepping mechanism responsive to the dial pulses from the dial unit of the monitorial room. Since all selections are made by advancing the rotary switch wipers a predetermined number of steps from a definite fixed starting point, the wipers must be fully returned to their home position after a previous connection is released before a new selection is started. To insure against too early dialing of a new selection after the release of a previous connection, the control relays, and consequently the ready lamp, are made unresponsive to the key lever switch *A* and the dial of the monitorial room until the rotary switch wipers reach their home position.

The calling digits for the desired line circuit are dialed by rotating the dial finger plate to the respective digits consecutively and releasing it in the same manner as dial telephones are operated.

For each such operation of the finger plate, the dial mechanism opens and closes the pulsing circuit as many times as the value of the digit. Each of those openings of the dialing circuit is relayed to the rotary switch step magnet by the pulsing relay *PR*, thus causing the rotating wiper contacts to be advanced along the arc of the rotary switch contact bank as many steps as the value of the numeral dialed.

For reasons of equipment economy and circuit simplicity, the design was engineered to permit the number of digits forming the dialing numerals for the different circuits to vary. For example, the following is typical of a monitorial directory:

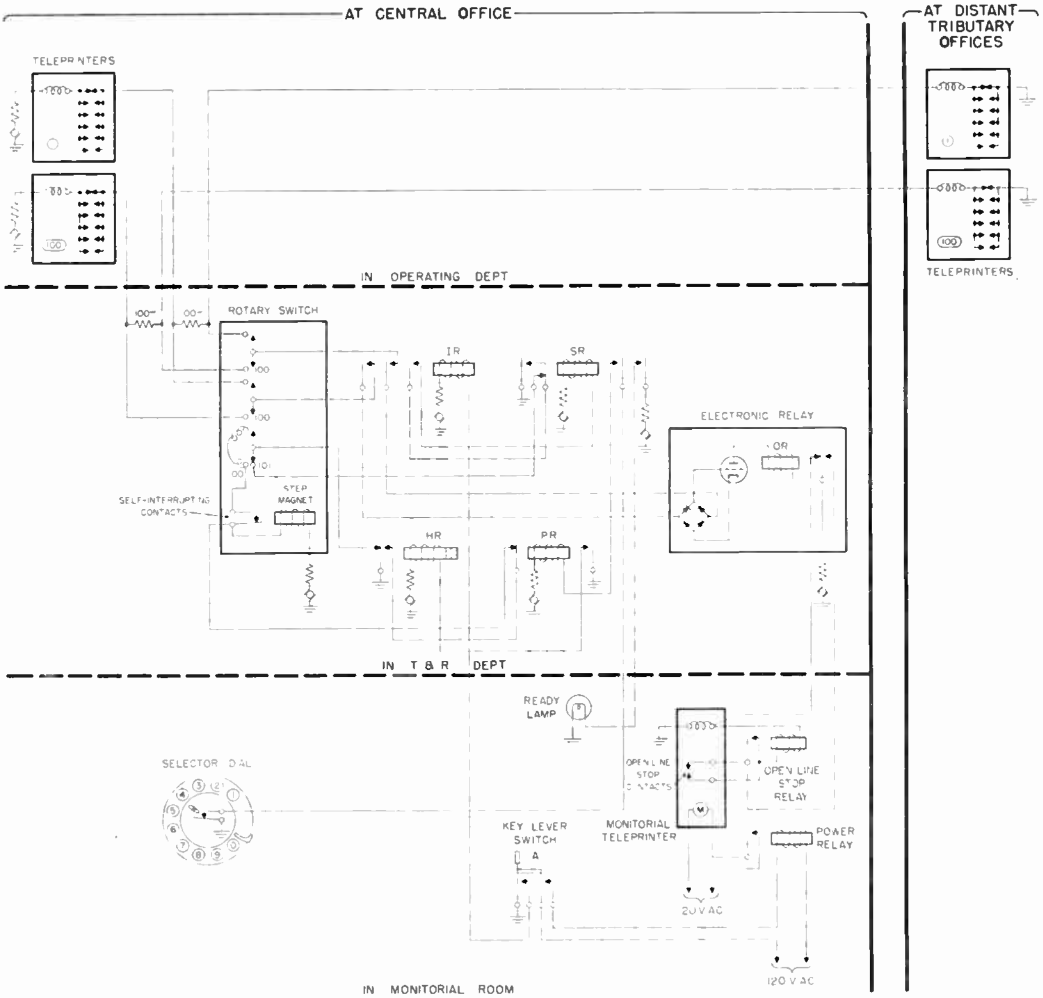

Figure 2. Diagram of switching arrangement

Office	*Office Call*	*Dial Number*
Waterloo, Iowa	WT	1
Fargo, N. D.	FG	2
Greaves Bldg. (Branch Office)	GV	01
Manitowoc, Wis.	MC	001
Readsburg, Wis.	RE	0001
Tomahawk, Wis.	TK	00001

The wiper contacts of the rotary switches are advanced one step for each dialing pulse. Hence, the distance that the wipers will advance for any dialing number will be the arithmetical sum of the digits forming the number except that the digit 0 represents the number 10. For example, the digit 1 will advance the wiper contacts one step; the digit 2, two steps; the digit 0, 10 steps; the number 01, 11 steps; the number 001, 21 steps; the number 0001, 31 steps; the number 00001, 41 steps, and so forth.

When the rotary switch wiper contacts are advanced to the selected position of the contact bank arc, they complete connections between the terminals of the selected line circuit series resistor and the electronic relay input terminals. A full wave rectifier, which forms a part of the electronic relay, is arranged between the input terminals and the electronic elements for automatically poling the input signals properly for actuating the electronic relay. It permits the effecting of connections between the terminals of line circuit resistors and the electronic relay without regard to the direction of current flow through the line circuit resistor.

As the current of the line circuit rises and falls for the transmission of the teleprinter signals, of course the voltage across the series line resistor varies in the same manner. That voltage variation causes a current to rise and fall in like manner in the parallel circuit containing the rectifier and the high value resistor

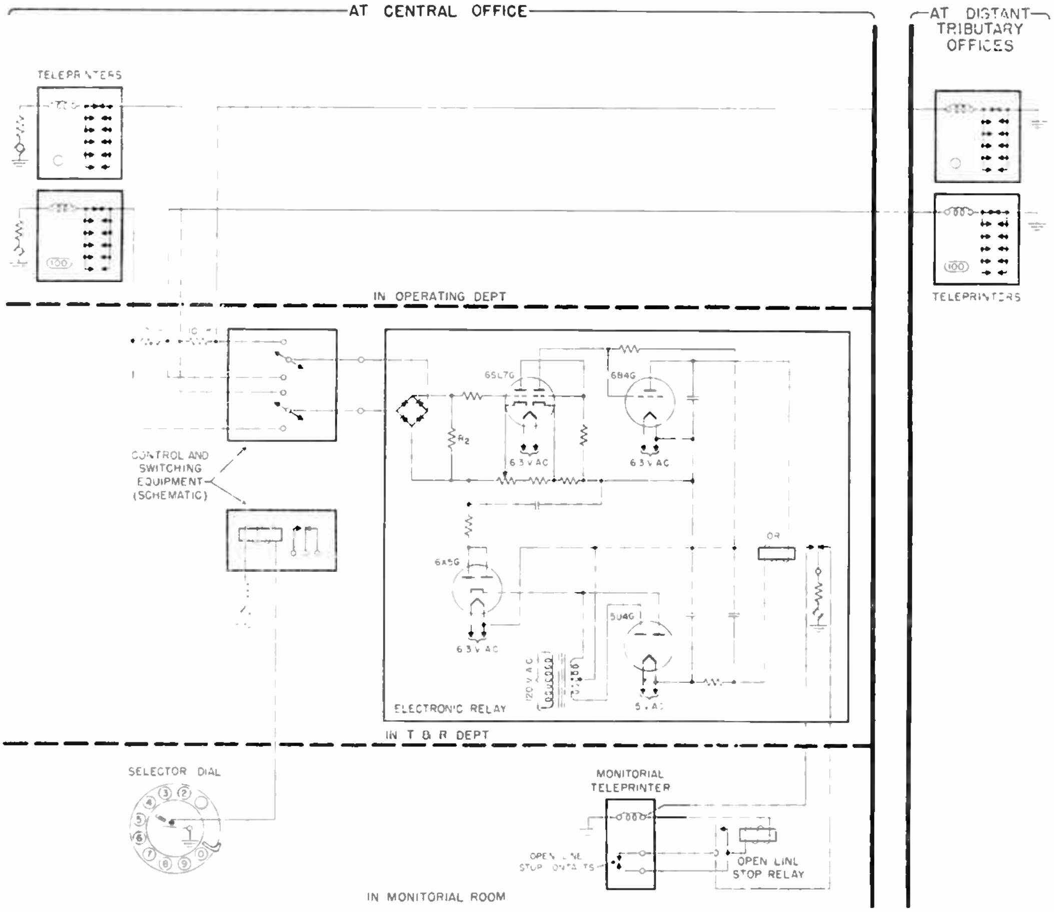

Figure 3. Diagram of electronic relay application

of the electronic relay illustrated in Figure 3. The latter current is of small magnitude, varying from zero to a maximum of only a few milliamperes.

The rectifier causes the current to flow through the high resistor R_2 in such a direction that the grid of the first triode of vacuum tube 6SL7G becomes sufficiently positive with respect to its cathode to cause current to flow in its respective plate circuit. That plate current causes the grid of the second triode section of the same tube to become sufficiently negative to cut off the plate current of the second triode section. The latter condition allows the grid of vacuum tube 6B4G to become positive with respect to its cathode causing current to flow through its plate circuit which includes the winding of the output relay *OR*.

When current is cut off in the line circuit, the opposite tube responses occur and the plate current of vacuum tube 6B4G is cut off causing relay *OR* to release. The operations of relay *OR* repeat the line teleprinter signals to the monitor teleprinter located in the monitorial room where a copy of the actual transmission is produced for monitorial purposes.

After a connection is made to a teleprinter line, it may remain established as long as desired, and all transmission over that line circuit will be recorded. When a monitorial observation of the selected line circuit is completed, the connection and all control relays are released by returning the key lever switch *A* of the monitorial room (see Figure 2) to its open position.

The release of the holding relay *HR* completes a circuit from ground, through the rotary switch third wiper and its associated stationary bank contacts, all of which contacts except the starting position point are multipled together through the self-interrupting contacts, through the stepping magnet to ground, causing the rotating wiper contacts to be stepped to their starting, or home, position.

Open Line Stop

The proper operation of some teleprinter circuits, such as way circuits of Reperforator Switching System Plan 21 offices, requires the occasional transmission of timed open signals. Since, normally, the closure of the circuit after such signals would cause a false character to be printed by a monitorial teleprinter connected to the circuit, an open line stop arrangement is used to prevent the recording of such erroneous characters by closing the circuit through the teleprinter operate magnet for line circuit openings greater than the length of one character. As illustrated by Figures 2 and 3, that arrangement consists essentially of a circuit containing a break contact on the output relay *OR*, winding of the intermediate holding relay (Open Line Stop Relay), and a pair of contacts (Open Line Stop Contacts) on the monitorial teleprinter. The latter contacts close momentarily during the last half of the fifth pulse and, when the output relay *OR* is released in response to an open line condition, they complete a circuit from battery at relay *OR* to ground at the teleprinter magnet through the winding of the open line stop relay and the tele-

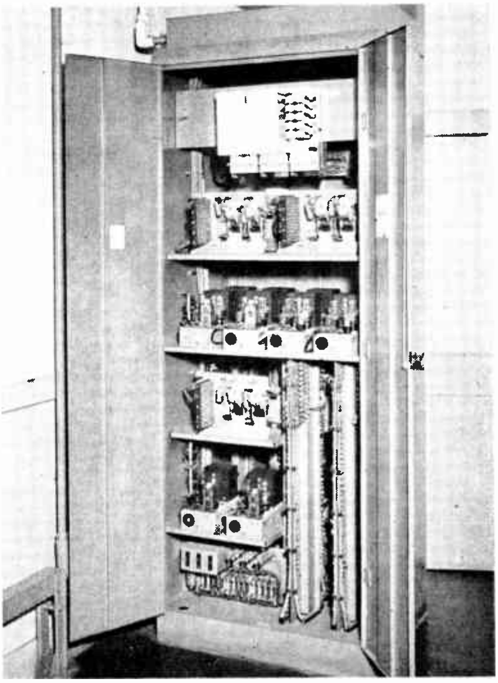

Figure 4. Monitorial switching equipment cabinet

printer magnet causing them to operate. The open line stop relay remains operated as long as the relay *OR* is released and holds the circuit closed through the teleprinter magnet. The operating of relay *OR* in response to a closed line condition opens the circuit through the winding of the open line stop relay causing it to release, and completes a circuit through its front contacts to the teleprinter magnet. The release of the open line stop relay restores control of the teleprinter magnet to the contacts of relay *OR*.

Equipment Location

All of the switching equipment, including the individual line 100-ohm resistors, normally is enclosed in a double-sided cabinet, Figure 4, designed to accommodate 6 monitorial circuits on each side, a total of 12 such circuits.

The equipment of the monitorial room is mounted on 2-position racks comprised of an upper and a lower position. A teleprinter and the associated dialing unit are mounted on each position, and as many racks are used as are required. Figure 5 which shows some of the monitorial teleprinter and dialing equipment of the Accounting Department monitorial room in Boston illustrates a typical arrangement of monitor racks.

Conclusion

The ease of selecting and connecting to desired line circuits, the secrecy of monitorial operations, the accuracy of reproduction, and the freedom from impairing line circuit transmission characteristics, are factors which make the new dial switching monitorial facilities an effective and substantial aid to the monitorial supervisory staffs of the large area offices.

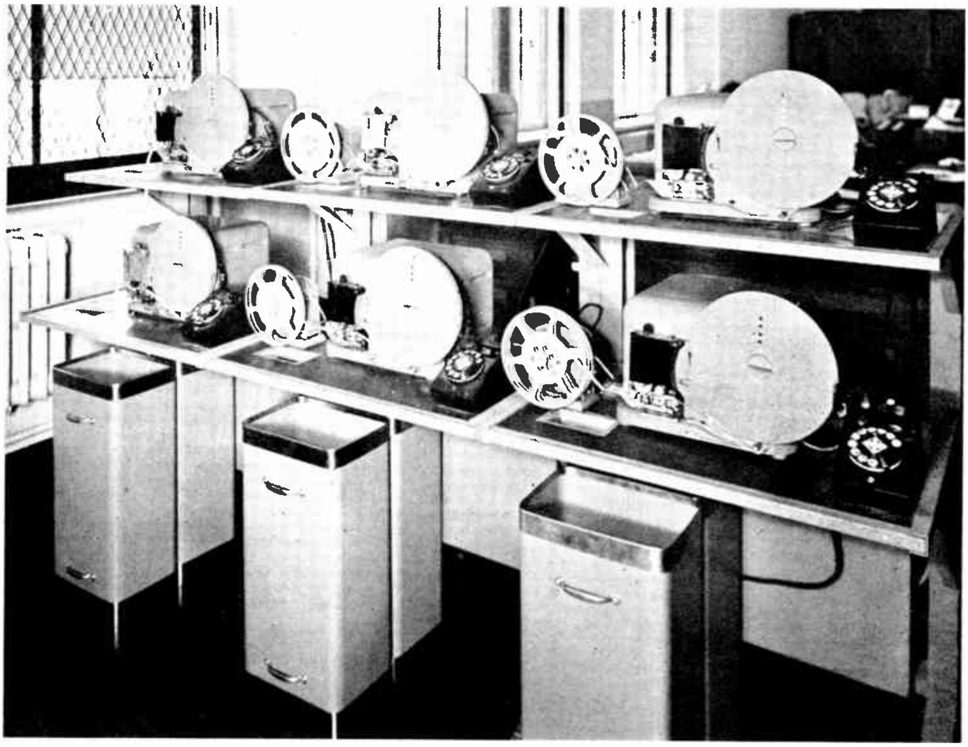

Figure 5. Two-position monitorial racks

THE AUTHORS: Photograph and biography of F. L. Currie appeared in the July 1948 issue of TECHNICAL REVIEW.

A. F. Connery, Director of Installation, P. & E. Department, received his first telegraph experience with the Great Northwestern Telegraph Company of Canada at Winnipeg, Saskatoon and Montreal. He worked for Western Union from 1920 to 1922 as a T. & R. attendant in the old operating room at 24 Walker St., then was with Postal from 1923 to 1928; International Communications Labs from 1929 to 1932, and All America and Commercial Cables from 1933 to 1938, during which time he was engaged in telegraph development engineering. He became Chief Engineer of Postal in 1939 and under his direction the Postal semiautomatic tape relay system was developed and installed. At merger in 1943 he became Central Office Engineer for Western Union and was appointed to his present position in 1950. A number of U. S. Patents have been issued in his name on regenerative and drop channel repeaters, switching systems, cable bias control equipment, cable code printers and cable translators. Mr. Connery received his technical education at Pratt Institute and Brooklyn Polytechnic Institute. He is a licensed Professional Engineer for the State of New York and a member of AIEE.

High-Speed Fax

THE POSSIBILITY of operating facsimile telegraph apparatus at much greater speeds than those usually employed has long been recognized. As a result many of the requirements of faster transmission and recording have been studied by Western Union research engineers during the 15 years since the Company began using the facsimile method for public telegrams.

The first models for an intercity high-speed Telefax terminal operating ten times as fast as Desk-Fax terminal equipment were completed at the Company's Electronics Research Laboratories in July 1949 and later put on test over the radio beam circuit between New York and Washington. Improved models of the new system, known as High-Speed Fax, were completed and demonstrated publicly in March 1951.

News reports have outlined this accomplishment. A technical article about the development will appear in a future issue of the REVIEW.

A Nation-Wide FM Telegraph Network

F. B. BRAMHALL and L. A. SMITH

The Origin of FM Telegraphy

The theoretical and technical aspects of recent advances in the carrier current telegraph art are well covered by the technical literature of record communication. Present-day amplitude-modulated carrier telegraphy is perhaps most comprehensively covered in an article written by A. L. Matte[1] which describes a 170-cycle-spaced channel system intended for single-printer working. A higher speed system with channels separated by 300 cycles, described by F. B. Bramhall[2] in 1940, was designed to provide transmission circuits for 4-printer multiplex working with a modulation speed of 132 bauds. Frequency-modulation systems for these two classes of service are covered respectively in two other papers by Western Union authors.[3, 4]

An extensive network of narrow-band AM telegraph channels, after the design covered by Matte, provides trunk circuits for the private-wire lease services and the teletype timed-wire service (TWX) operated by the American Telephone and Telegraph Company. Now with d-c physical circuit telegraphy largely displaced for trunk-line services in Western Union's plant, there has come into being a nation-wide network of narrow-band FM telegraph channels. Over the past several years, considerable work has been done in an effort to establish the relative merits of the AM and FM methods for various conditions of operation. The results of this work also have been recorded by various authors, notably T. A. Jones and K. W. Pfleger,[5] J. R. Davey and A. L. Matte,[6] and briefly in some of the articles already mentioned. For the most part, the comparisons recorded have been the result of laboratory work or short-term service trials. Now the operating results achieved on a narrow-band FM network can be reported as based on years of experience with nearly two million miles of such circuits.

First Large-Scale Application

In 1946, Western Union undertook a modernization and mechanization program which resulted in a tremendous expansion of its existing carrier network. This involved a conversion of multiplex circuits previously employed for trunk-line service to single-printer operation, and a replacement of the d-c physical circuits with carrier channels. The program covered practically all long-haul facilities and a large part of the shorter feeder circuits. A full appreciation of the conditions under which these circuits operate and the high performance standards demanded will be enhanced by an understanding of the routing and automatic switching methods by which separate telegraph circuits are interconnected in the modern telegraph plant. Manual relaying, the process of reproducing the telegraph message on paper and retransmitting it by a telegraph operator, has practically disappeared. A few relatively large reperforator switching offices have been established in heavily-loaded traffic centers. Each such office serves a selected territory or area, all messages to and from that area being routed through the switching center and automatically or semiautomatically retransmitted to the offices of destination. A description of the reperforator switching system which obviates manual handling and which now serves the entire nation is recorded in a paper by R. F. Blanchard and W. B. Blanton.[7] Fifteen switching centers are interconnected by a multiplicity of FM carrier telegraph channels as they are also connected to a great many smaller centers within each area. Only

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the very short circuit connections and those serving smaller towns remain on physical d-c telegraph wires.

Equipment

Present-day VF bands, either those derived from Western Union wire line or radio relay carrier systems, or those leased from A. T. & T. and the associated companies, have a bandwidth of approximately 3000 cycles. It has been found expedient to subdivide such bands into two subbands, and to operate eight or nine telegraph channels in each subband. To provide maximum flexibility with minimum variety in the types of equipment required, the carrier equipment is built up of standard units arranged to meet various conditions. The telegraph channel terminals are normally assembled in groups of eight, completely wired on a 10-foot rack. These terminal sets, shown in Figure 1, are wholly electronic, the outgoing carrier being frequency-modulated by the telegraph printer or other transmitting machine and the incoming carrier being detected and amplified to a power level sufficient to drive the reperforator or printer on the receiving side. Designed specifically for single-channel teleprinter service, they are capable of meeting the three most commonly required d-c leg conditions—full duplex, half duplex and carrier terminals tandem-connected back to back. The eight channels normally comprising one group of terminals have mid-frequencies spaced 150 cycles apart with the lowest channel centered at 525 cycles, and the highest at 1575 cycles.

Figure 1. Channel terminal equipment in large office

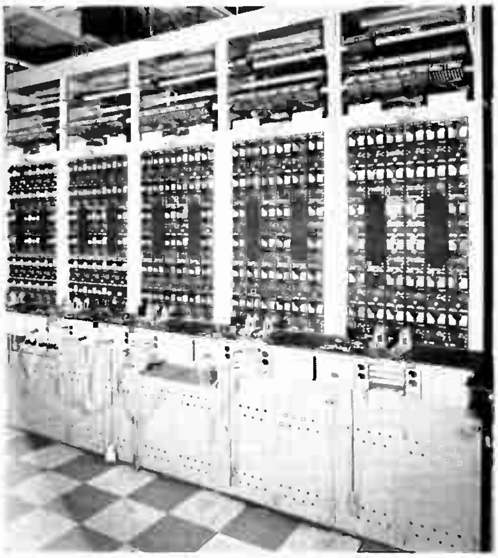

Figure 2. Centralized control and monitoring equipment for 160 channels

The regulating equipment, such as rheostats for building out leg resistance, bias adjusting potentiometers, common test equipment, etc., is divorced from the channel terminal bays and concentrated at a central location in the operating room. Several different arrangements are used for assembling the standard control items, each arrangement being designed for a given class of office. Figure 2 illustrates a typical method, employed at larger offices, with each of the five cabinets shown serving four groups of eight or nine channels per group. In this instance each group has been provided with only eight channels, the blank panels being left for future expansion.

Figure 3 shows schematically the subband separation and modulation equipment employed with this method of working. The method has two distinct advantages. First, manufacturing and warehousing economies are effected in that the number of different types of oscillators, filters, and discriminators required is only half that needed under the older pattern where all frequencies required to fill the voice band were directly generated, selected, and detected. Second, the smaller group of channels is found a more convenient unit from the standpoint of traffic routing and dispatching, since a large part of the total network is comprised of feeder circuits to smaller communities which can be served by the small group of channels. This advantage results in the extension of subbands from one system to another by means of subband patches as illustrated in Figure 4.

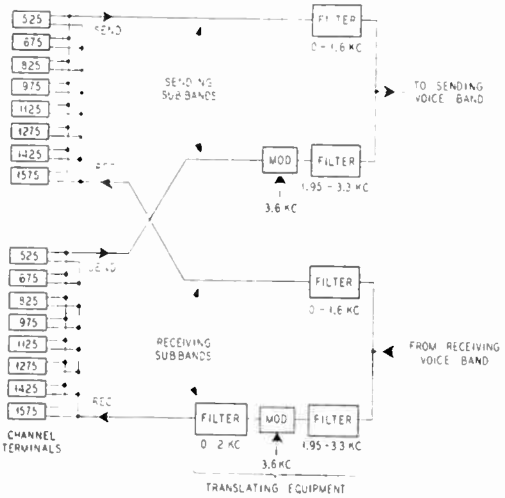

Figure 3. Block diagram of subband grouping

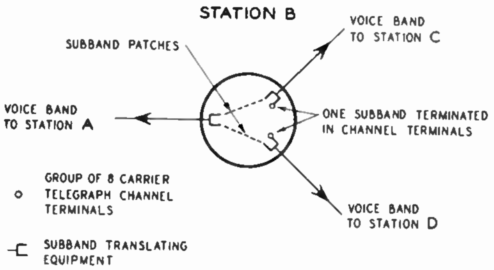

Figure 4. Typical subband interconnections

Patches between complete bands, without separation into subbands, are also employed.

Voice bands over which the channels are operated are derived from a number of sources as dictated by circumstances. Still, to the telegraph channels all voice bands appear as two unidirectional paths (4-wire circuits) whether the ultimate transmission medium be a 2-wire or a 4-wire high-frequency carrier or a radio relay system. Commonly used transmission mediums are Western Union's own 2-wire and 4-wire carrier systems, which range in capacity from one subband in either direction using a top frequency of 3 kc, to the 150-kc radio relay system which handles 64 subband groups.[8] In leased A. T. & T. facilities, channel groups, usually not less than two subbands, operate on C, J, K and L carriers.[9, 10, 11, 12]

The full capacity of the voice band is, of course, not realized when its load is only two groups of eight channels each. On many circuits where the traffic demands, a total of 20 channels are operated in the voice band by the expedient of assigning the frequency spectrum as depicted in the chart of Figure 5. Two additional channels are secured by adding the 375-cycle J channel to each group. If need be, the 19th and 20th channels, the K and L, are added, completely filling the space left as a guard band between the subband filters. These channel allocations are 1725 and 1875 cycles, respectively, maintaining the 150-cycle separation pattern.

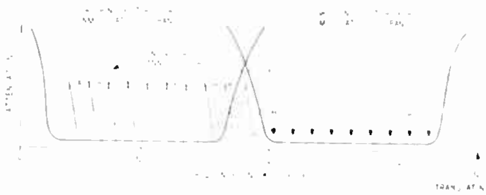

Figure 5. Channel allocation chart

Circuit Layouts

Figure 6 is a circuit map of the trunk carrier telegraph channels now operated

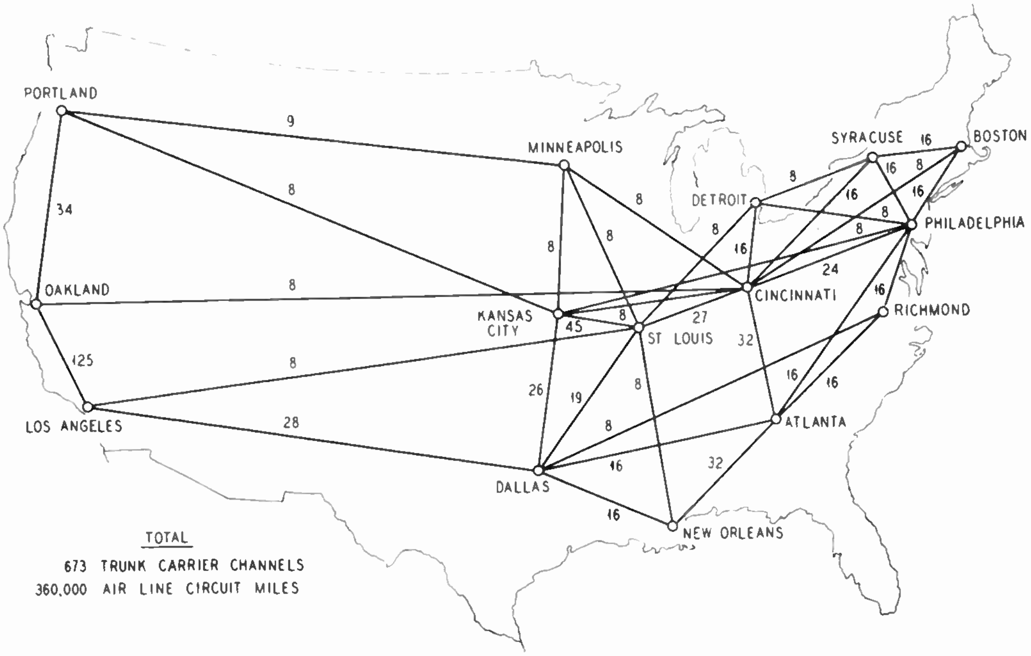

Figure 6. Direct FM carrier telegraph channels between switching centers

between the reperforator switching centers. This map does not show trunk connections to New York, Chicago, or Washington, three major traffic centers which originate a substantial proportion of the nation's telegraph traffic. Figure 7 shows the trunk carrier circuits of the New York office, which is typical of the three major offices which are not actually switching centers but which involve large networks of carrier trunk circuits.

Circuits are considered as direct carrier trunks if they are derived from two or more carrier bands with a patch between

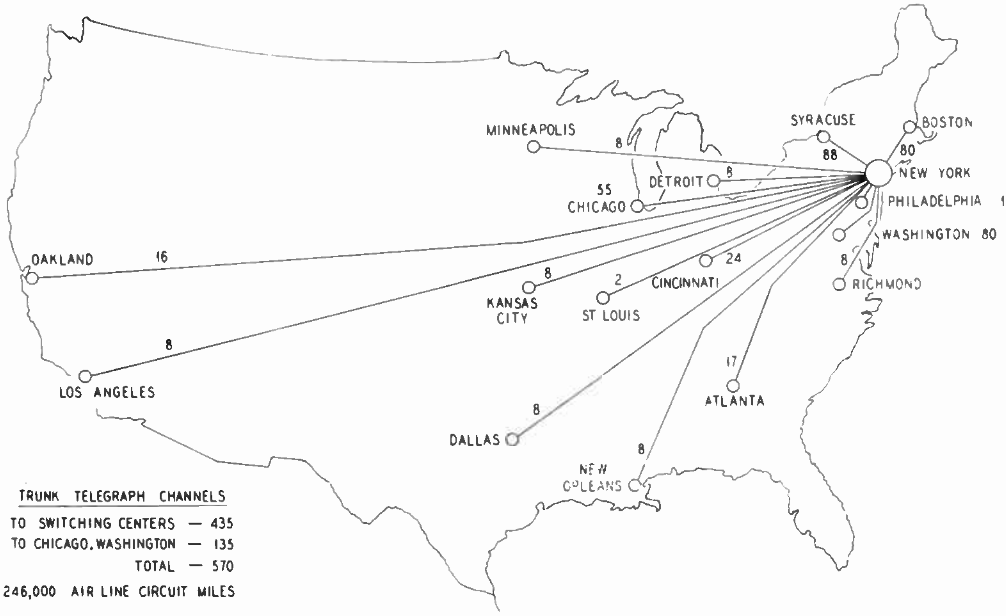

Figure 7. Direct FM carrier telegraph channels serving New York City

subbands or bands, the criterion being a continuous carrier frequency connection without intermediate conversion down to d-c signals. Where eight or nine channels suffice for trunk service between two traffic centers, a voice band between these centers is not completely utilized. The remaining capacity is, therefore, employed for establishing trunk service to some other distant center by a subband patch.

Referring to Figure 6, it will be seen that direct carrier trunks as defined above are not always provided between a given switching center and all other switching centers. Where a group of direct carrier trunks is not justifiable, carrier transmission is obtained by a d-c telegraph patch between two trunk carrier circuits. As an example, a Boston-Minneapolis connection is easily established by a d-c leg connection between a Boston-Cincinnati channel and a Cincinnati-Minneapolis channel.

The use of carrier circuits for all trunk services has proved an economical application of modern techniques. Still in large measure the success of Western Union's switching system and carrier network can be credited to the so-called tributary carrier circuits which connect various points in each area to the switching centers. The term "tributary circuit" as used here also includes circuits operating to certain important telegraph offices, such as Buffalo, Cleveland, Denver, Pittsburgh, etc., since business from these points is routed via the automatic reperforating equipment at the established centers. Tributary circuits spread out radially from the switching centers as illustrated by Figure 8.

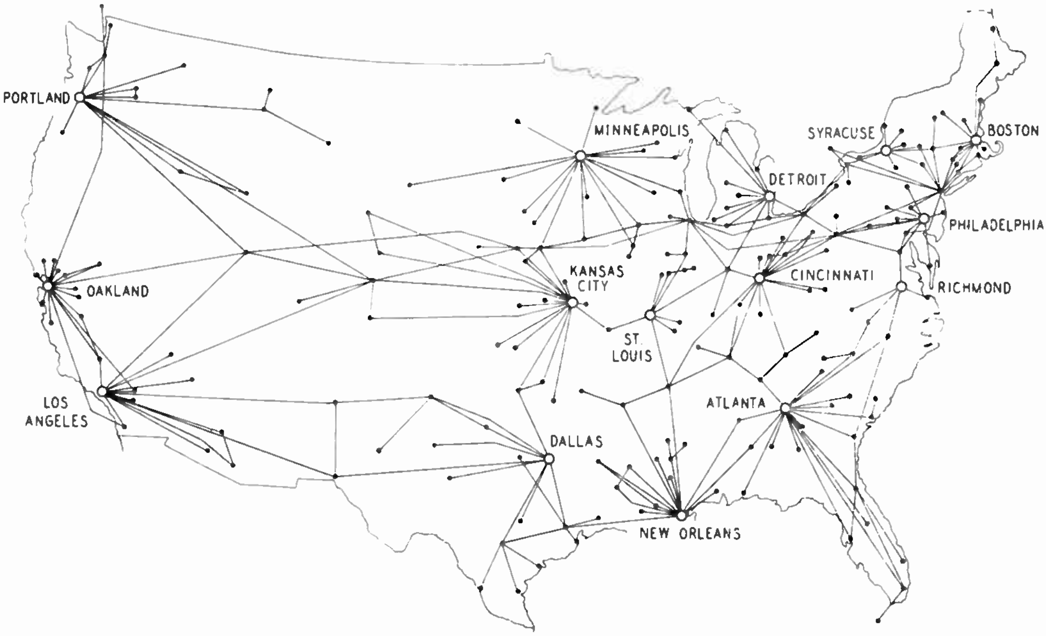

Figure 8. Tributary FM carrier circuits

The average switching center is equipped with 400 channel terminals, one-third of which operate in trunk-line service and two-thirds to scattered locations in the area. Figure 9 shows the assignments for the 318 channel terminals located in Minneapolis, a typical example; 103 of the channels are assigned to trunk service and the remaining 215 provide carrier service to 16 towns and cities in the area. These tributary carrier circuits bring all the major cities, and the small towns as well, within direct reach of the reperforator switching mechanisms. Many of them are extended via d-c telegraph facilities as illustrated in Figure 10. Here a small town, *A*, operates via a relatively short d-c telegraph line into a carrier channel terminal in the tributary office, *B*, and thence via a carrier channel direct to the switching center at office *C*. Business originating at *A* is manually transmitted on a teleprinter circuit; but there is no handling of any kind at *B*, and at *C* the circuit terminates directly in the switching equipment which automatically handles the required retransmission.

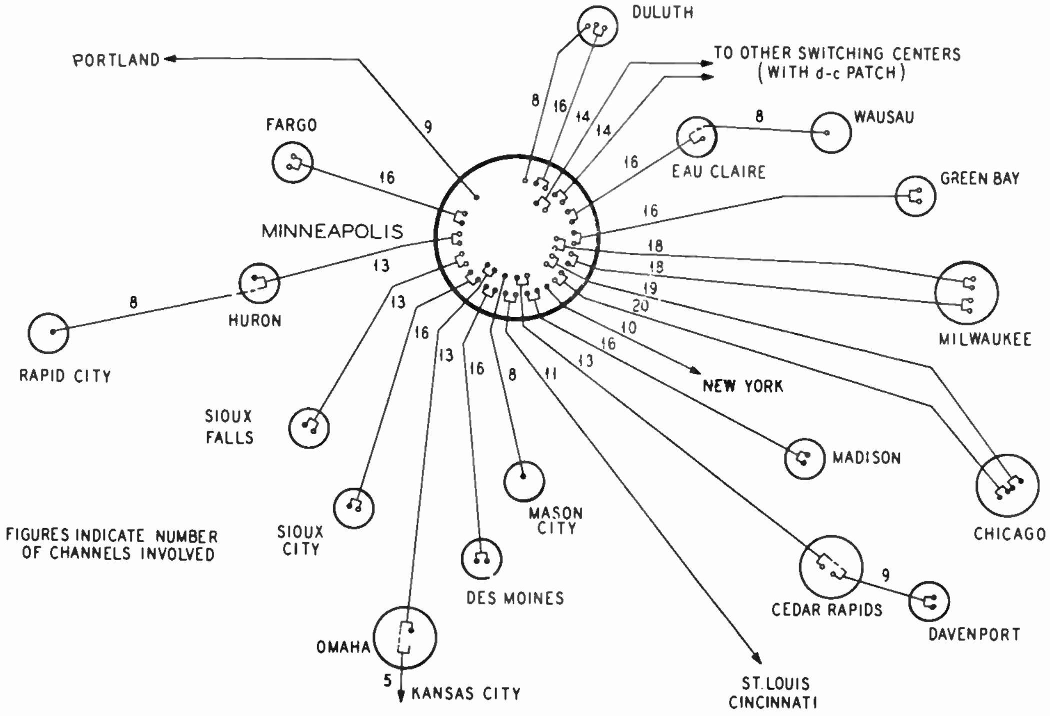

Figure 9. FM carrier channel assignment of typical area center

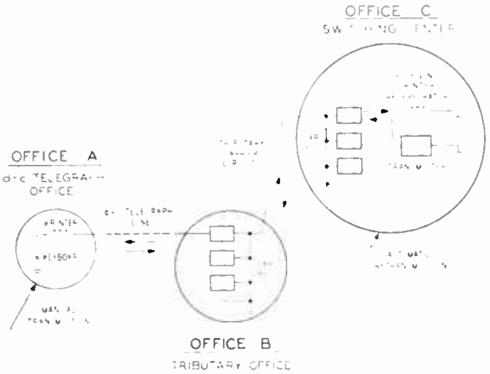

Figure 10. Typical tributary circuit arrangement

All manner of direct telegraph connections, or the equivalent of direct connections without manual handling at intermediate points, are established by this arrangement. Nearly 6000 channels are now in operation, totaling almost two million circuit miles. Of this number, about 1800 are employed for direct trunk connections, and around 4000 for tributary circuits. The switching facilities provided at reperforator centers permit almost instantaneous connections between any two points in the network, regardless of the size of the offices involved or their locations.

Operating Performance

From the viewpoint of the traffic engineer, operating performance is measured in terms of teleprinter range and continuity of service provided. Distortion losses due to filters and electronic equipment are extremely small. When a teleprinter circuit is operated through one carrier section the range obtained is practically a short-circuit range. Where two or more carrier sections are operated in tandem (with or without intervening relays at repeaters inserted for obtaining drops), the operating range decreases slightly with each added section. Figure 11 shows this effect. It is quite inevitable that any data such as recorded by this graph are gathered under more or less "controlled" conditions. Still every effort was made, by continued repetition of measurements and by performing the tests on more than one set of tandem-connected channels, to get the best possible indication of the performance to be expected in traffic service. Whenever more than seven or eight tandem sections are involved in a given circuit, intermediate regenerative repeaters are provided to reduce the net effect and insure a minimum teleprinter range of at least 65 points.

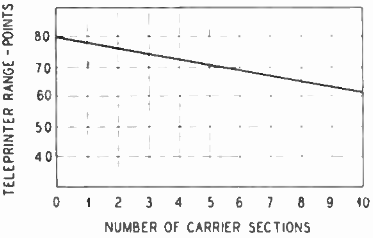

Figure 11. Effect of tandem sections on teleprinter range

Since any interruption requires transferring traffic to parallel facilities, or rerouting via other cities to maintain a telegraph connection, minimum lost time on each circuit is important. The improvement in continuity of service obtained from the use of the carrier network can be illustrated by examining the results of a lost time study made on a transcontinental circuit. One of the few remaining multiplex circuits was used for this time study because it permitted a direct comparison of the same traffic circuit under an all-grounded condition (13 repeater sections) and an all-carrier condition (2 carrier sections with d-c leg patch between). The all-grounded circuit employed two regenerative repeaters.

LOST TIME ANALYSIS

2ND NEW YORK—OAKLAND 2-CHANNEL MULTIPLEX
24-HOUR-A-DAY OPERATION

May 1946
All-Grounded Circuit
13 Repeater Sections

Trouble	*No. of Delays*	*Delay in Minutes*
Wire Trouble		
Nyk—Chgo	4	162
Chgo—Denver	8	311
Denver—Oakland	12	233
Circuit Lineup		
Daily Over-all	27	810
Partial	40	1021
Other Trouble		
Fails and Clears	13	111
Earth Currents	6	135
Equipment	5	63
Loss Synch.	71	84
Misc.	4	50
Total	190	49 hrs. 30 min.

August 1950
All-Carrier Circuit
2 Carrier Sections

Trouble	*No. of Delays*	*Delay in Minutes*
Carrier Circuit Failure	12	151
Loss Synch.	25	25
Fails and Clears	4	9
Total	41	3 hrs. 5 min.

The tremendous decrease in lost time with carrier operation is attributable to several major factors:

a. Present-day carrier circuits operate on all-cable leased facilities in many cases, and since cable circuits are less subject to failure than open-wire lines formerly employed, the number of interruptions is decreased. When an interruption occurs, the time required for circuit restoration is comparable for grounded and carrier circuits, but a circuit lineup is not ordinarily necessary for carrier whereas 8-10 minutes usually were consumed by circuit realignment after a wire failure on a long-distance grounded circuit.

b. Routine or emergency circuit lineups which required considerable time on the long grounded circuits are practically eliminated with carrier operation. The lineups on grounded circuits were necessitated primarily by balance changes due to variable weather conditions.

c. Certain types of trouble, such as earth currents, affect grounded circuits but have little or no effect on carrier circuits.

d. Failures which clear without location of exact cause are more prevalent on grounded circuits.

A similar improvement in the operation of long-distance teleprinter circuits has been experienced, but comparative data cannot be presented because all long-distance circuits in the Western Union network were operated multiplex before the advent of carrier. However, studies of existing long-distance teleprinter circuits substantiate the excellent continuity of service obtained from carrier operation. A few such circuits, selected at random, show the following total lost time for a 1-month period:

Circuit	*No. of Carrier Sections*	*Total Lost Time*
New York—San Francisco	2	36 min.
New York—Los Angeles	2	53 "
New York—Denver	2	1 hr. 46 "
New York—Houston	3	1 " 22 "
New York—San Antonio	5	1 " 40 "

Shorter circuits show considerably less lost time, many operating without interruptions of any kind for an entire month or longer.

One further example of operating performance, which clearly illustrates the reliability obtained, is the "round-robin" circuit of Figure 12. This circuit consists of a continuous loop with 23 individual carrier sections, totaling approximately 3300 miles connected in tandem. Two independent message circuits, one operating clockwise and one counterclockwise, are established by this arrangement, with transmission originating at any one of 31 customers' stations scattered around the loop. Transmission from any given point is received at all other points. In spite of its complexity, the total lost time for all points in the circuit averages only 0.6 percent.

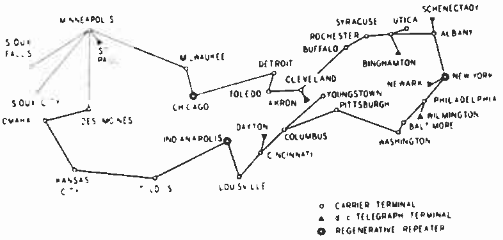

Figure 12. 3300-mile circuit involving many FM carrier sections

Conclusion

Limited field installations during the 1930-1940 trial period convinced Western Union that FM operation was more desirable than AM for a carrier telegraph plant, and also that carrier operation would be more advantageous than d-c physical operation. The results of a moderate increase in the carrier facilities a decade ago, followed by wholesale conversion in the past few years, have confirmed this conclusion. Installation, operation and maintenance have been economical and the continuity of service obtained has improved to a marked degree.

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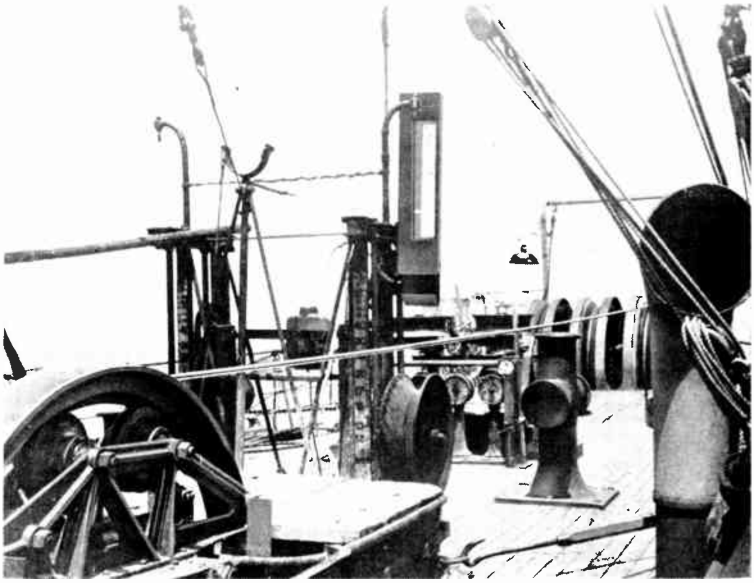
THE AUTHORS: Photograph and biography of F. B. Bramhall appeared in the October 1948 issue of TECHNICAL REVIEW.

L. A. Smith joined the Engineering Department of the Telegraph Company in 1929 about a year after graduating from Northeastern University. The first major carrier project undertaken by Western Union, between New York and Buffalo, occupied his full time from the beginning and served as the starting point for his long carrier career. He has been actively connected with the design, installation, testing, and operation of all carrier projects that have materialized since that time. He has also been engaged in handling transmission problems for both carrier and long distance facsimile, and was involved in the Cablephoto system for facsimile transmission from London. Mr. Smith was transferred to the P. & E. Department in 1946 where he continued his carrier work. At present he is assigned to the office of the Planning Engineer.

C. S. "Lord Kelvin" Lays Telephone Cable

THE ACCURACY with which Western Union's cable ship *Lord Kelvin* placed two new submarine telephone cables is told by J. J. Gilbert in the *Bell System Technical Journal* for January 1951. A condensed report appears in *Electrical Engineering* for March.

"In April of last year," writes the author, "there was installed between Key West, Florida, and Havana, Cuba, a submarine telephone cable system . . . It was felt desirable, however, to build the drum on the *Lord Kelvin* out to an 85-inch diameter to match the diameter of the bow sheaves. The dynamometer sheaves and the sheave leading the cable off from the brake drum presented more of a problem. The lead-off sheave was replaced by a ring sheave, 85 inches in diameter, supported on wheel bearings. The frame supporting these bearings was hinged at one end and the pressure on the other end of the frame, due to the tension of the cable passing over the sheave, offered a ready means for measuring this tension. For this purpose a resistance pressure cell was employed with a recorder, which not only gave a continuous record of tension but also relayed the signals to a vertical indicator on deck for the guidance of the brake operator, and to a smaller indicator on the bridge."



Courtesy Bell System Technical Journal

Special ring sheave (left), tension indicator (center), and bow sheaves on deck of Western Union Cable Ship Lord Kelvin

This arrangement with the ring sheave on wheel bearings as designed by C. S. Lawton, General Plant Engineer in the Western Union International Communications Department, is illustrated.

"The conditions for cable laying between Key West and Havana are far from good," continues the author. "The Gulf Stream is swift and erratic. The velocity of the current at any particular point as indicated by the stream at the buoys was found to vary considerably over a fairly short period of time. As an indication of the degree of precision obtained by careful navigation of the ship, the final results show that in each of the cables the specified length was missed by only .2 n.m., which is quite an unusual achievement.

"Acknowledgment is made to the Western Union Telegraph Company, the owners of the *Lord Kelvin*, for their cooperation in providing the special equipment for the ship and to the Captain of the *Lord Kelvin*, his staff and crew, for the very satisfactory performance of the laying operation."

Captain Richard Beadon is the master of the Cable Ship *Lord Kelvin*. The Navigating Officer is Mr. Eric P. Gough.

Public Address System Used In Western Union Reperforator Switching Centers

R. W. GOOD

VOICE COMMUNICATION between supervisors of related equipment in different sections of the new Western Union reperforator switching centers is used to expedite the traffic of telegrams therein. Telegrams are transmitted through the centers at high speed without manual retransmission, but occasionally situations develop which demand immediate attention to avoid congestion. As supervisors constantly move through the aisles of the centers and are not in position to receive or send trouble calls from a fixed position, a public address system was chosen as the most suitable means of communication to obtain the desired results.

Design of Public Address System

The size of the centers, the number of supervisory messages, and the number

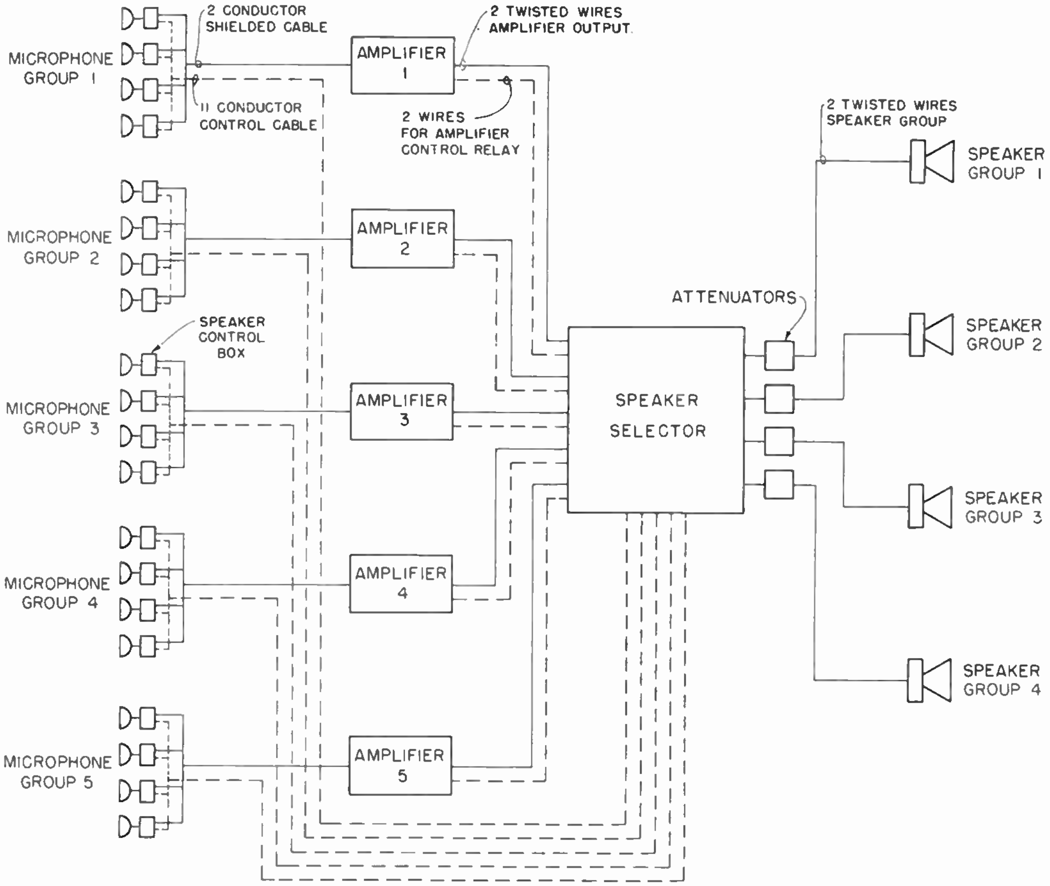


Figure 1. Block diagram of public address system

A paper presented before the Winter General Meeting of the American Institute of Electrical Engineers in New York, N. Y., January 1951.

and nature of equipment sections necessitated the design of a public address system having the following qualifications:

1. Provisions for two-way communication between equipment supervisors in different sections and between equipment supervisors in the same section.
2. Provisions preventing one announcement from tying up the entire public address system.
3. Provisions for indicating the busy portions of the public address system.
4. Provisions for maintaining the speaker groups at different output levels.

A block diagram of the public address system is shown in Figure 1. There are five groups of microphones each with an amplifier, and four groups of loudspeakers. Each microphone is connected to a speaker control box containing lamps for indicating busy portions of the system and switches for selecting the desired speaker group. The switches in the speaker control box connect the microphone to the input of the amplifier and establish circuits which cause the speaker selector to connect the desired speaker group to the amplifier output. A variable attenuator has been inserted between the speaker selector and each speaker group to preset the output level of the speaker group. This system is capable of handling four simultaneous announcements, provided four microphones in different microphone groups are used and different speaker groups are selected.

As set forth in the provisions listed above, any microphone may be connected to any speaker group, one announcement does not tie up the entire system, busy portions of the system are indicated, and individual volume controls are provided for each speaker group.

Location of Microphones and Loud-Speakers

In a reperforator switching center microphones and loud-speakers are distributed among the equipment racks and tables at frequent intervals for the convenience of operators and supervisors. Typical methods of mounting are shown in Figures 2 and 3. Since in many cases it is necessary to place microphones and speakers in locations where a high noise level exists, the public address system was designed to minimize as much as possible interference from such high noise level.

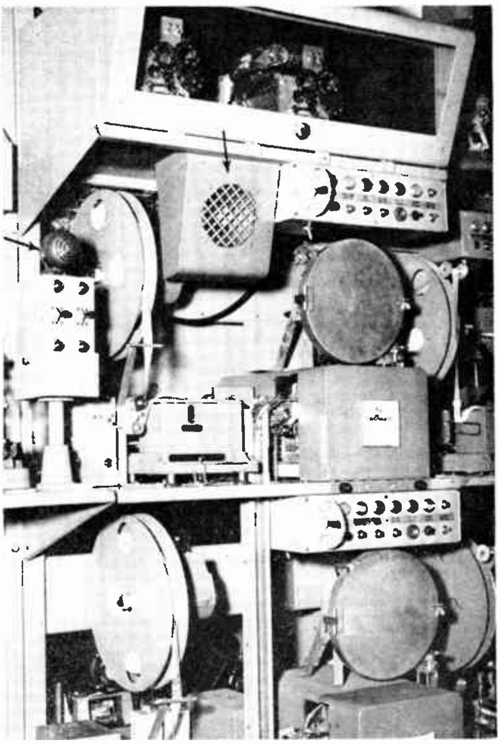


Figure 2. Typical method of mounting microphone and loud-speaker at sending positions

Microphones

The microphones used are unidirectional dynamic type with a balanced ungrounded output. The output level is approximately 50 decibels below 1 volt per dyne per square centimeter at an impedance of 200 ohms. Use was made of unidirectional microphones to reduce the pickup of background noise. At a large reperforator switching center such as the one at Boston, Massachusetts, the largest microphone group contains 32 microphones.

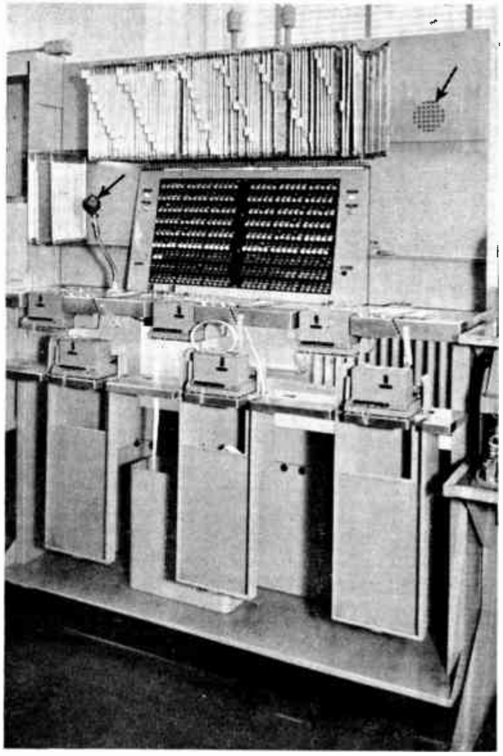


Figure 3. Typical method of mounting microphone and loud-speaker at push-button positions

Speaker Control Box

One type of speaker control box with microphone is shown in Figure 4. The box is mounted on a subbase and contains indicating lamps and lever switching keys. The lamps indicate the condition of the group the microphone is in, and the condition of the speaker groups. The glowing of the lamp at the top of the box indicates a busy microphone group. The glowing of the lamps on the front of the box indicates busy speaker groups. When a speaker group is busy the indicator lamp for that group glows on all speaker control boxes in the system. At the reperforator switching center at Boston, 90 speaker busy lamps glow simultaneously. To maintain the current supplying this number of lamps at a low value, 1/25-watt, 110-volt neon lamps are used. The 90 neon lamps in multiple draw a current of less than 100 milliamperes.

The lever switching keys are used to connect the microphones to the microphone cable and select the desired speaker group. Operation of either key up or down makes the connection to the microphone cable, the up position selecting one speaker group and the down position another. The lever switching keys are the leaf spring type commonly used on telephone switchboards. The spring contacts are made of palladium which is nonmicrophonic and highly resistant to tarnish, which features are important when switching the low level output of a microphone. Each position of the lever switching key is provided with two separate spring contact pileups. One is used for the microphone circuit and the other for the control circuits, thus minimizing the chance of interference between the control and the microphone circuits.

The speaker control boxes are mounted on the subbases by means of an 18-contact connector. This arrangement facilitates the replacement of a faulty microphone or speaker control box with minimum loss of service.

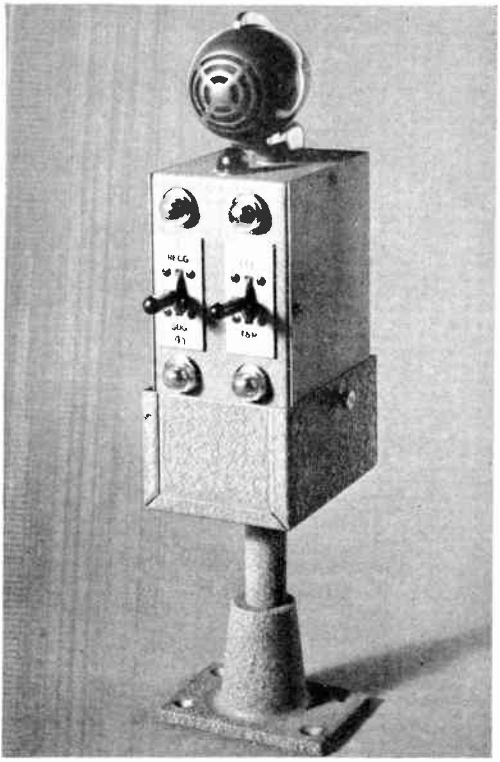


Figure 4. One type of speaker control box with microphone

Cables

The public address system at most reperforator switching centers covers areas on several floors. The amplifiers, speaker selector, and attenuators are centrally located to obtain the shortest possible connections to microphones and loud-speakers.

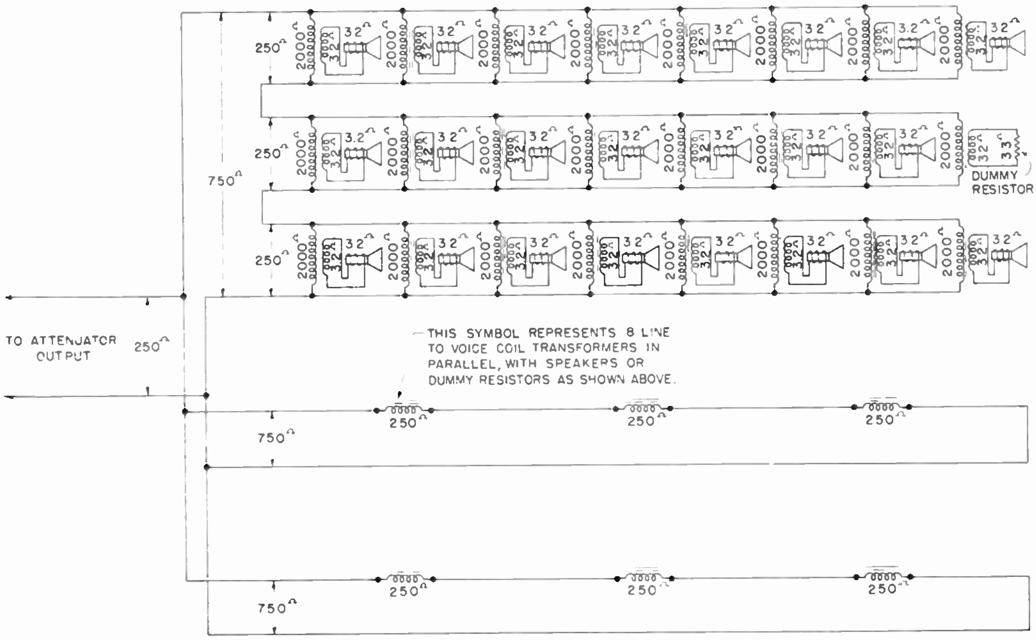
The microphone cables in many instances are necessarily in close proximity to telegraph circuits. To minimize pickup and loss of signal due to attenuation, the microphone cables used are 2-conductor shielded with a terminating impedance of 200 ohms and operated at the low level derived from the output of the dynamic microphones. The control cable is a 10-conductor cable which provides circuits between all the speaker control boxes in a microphone group and the speaker selector. for the operation of indicator lamps at the microphones and of relays in the speaker selector.

Each group of speakers is connected to the output of an attenuator by means of a twisted pair of wires. The size of wire used. No. 16 American Wire Gauge, maintains the power loss in the wires at a value less than 5 percent with an impedance of 200 to 250 ohms reflected from a speaker group.

Loud-Speakers

Two methods of obtaining loud-speaker coverage to overcome the high noise level experienced in portions of the reperforator switching centers were considered. One method was to use a few large speakers sparsely located and operated at an output level sufficient to cover a desired area. The second method considered the use of a large number of small speakers, each covering a small portion of the total area and operating at a reduced output level. The second method was considered the more desirable, for the following reasons:

1. The output of each small speaker may be so reduced that a large group of small speakers requires less audio power to provide adequate speaker coverage in a definite area than a small group of large speakers.
2. Operators and supervisors move up and down aisles tending equipment on either side, and would find working in close proximity to a speaker operating at a high output level undesirable.



THIS SYMBOL REPRESENTS 8 LINE TO VOICE COIL TRANSFORMERS IN PARALLEL, WITH SPEAKERS OR DUMMY RESISTORS AS SHOWN ABOVE.

Figure 5. Schematic wiring of a typical group of loud-speakers

There are areas in a reperforator switching center where a few large speakers mounted on walls or columns are used, but in these cases the noise level is not great and the areas to be covered are small. At the reperforator switching center in Minneapolis, Minnesota, the largest speaker group contains 66 5-inch permanent magnet speakers.

Figure 5 shows the schematic wiring of a typical speaker group. The speakers are equipped with universal line to voice coil transformers and are series-parallel connected to obtain a line impedance of 200 to 250 ohms. To obtain the same volume from each speaker in a group, the parallel legs are composed of an equal number of speakers or dummy resistive loads using equivalent impedance taps on the line to voice coil transformers.

In the placement of microphones and speakers on equipment racks and tables, there are cases where a microphone and speaker are located with respect to each other in such a manner that acoustic feedback could occur when announcements are made within the same section. To overcome this fault, the voice coil circuit of the offending speaker is disconnected by the operation of the lever switch at the microphone which selects the speakers in this section.

Amplifier Cabinets

The speaker selector, attenuators, and amplifiers are mounted in cabinets shown in Figures 6 and 7. Cabinet 1, on the left in Figure 6, contains the speaker selector, the speaker group attenuators, and the power compartment. Cabinet 2 is equipped to contain six amplifiers, a monitor microphone and speaker, and indicator lamps.

Speaker Selector

The speaker selector in Cabinet 1 contains 20 relays for connecting any one of the five microphone groups to any one of the four speaker groups. The scheme of operation is shown by Figure 8. Each vertical row of relays is associated with a microphone group, and each horizontal row with a speaker group. The relays are telephone type switching relays mounted on octal tube bases. As with the lever switching keys in the speaker control boxes, palladium contacts are used on the relay springs.

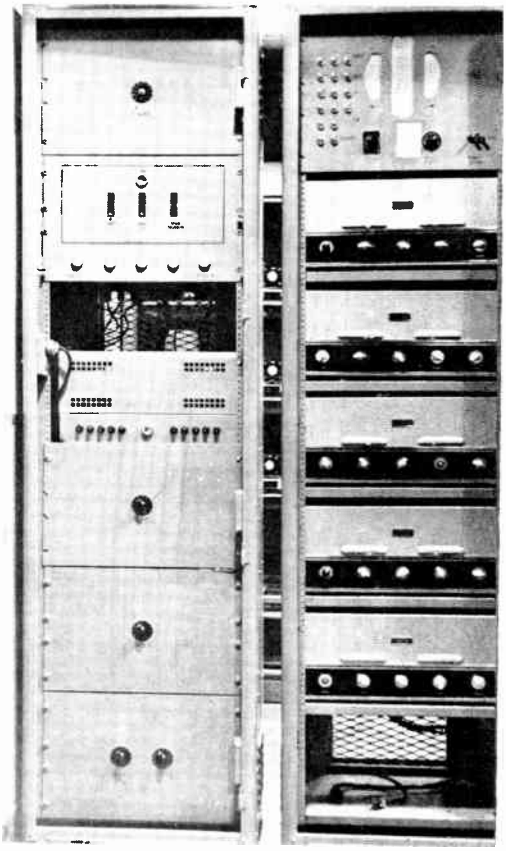


Figure 6. Front view of cabinets containing the speaker selector, attenuators and amplifiers

Attenuators

The speaker group attenuators are 250-ohm variable "T" pads, which are panel mounted and capable of attenuating the amplifier outputs from 0 to 30 decibels in 3-decibel steps. At present all speaker groups are attenuated; however, the wiring for the attenuators is arranged so that if the speaker system expands to the extent that the present amplifiers are incapable of delivering enough power to the speakers, the attenuators may be replaced by booster amplifiers.

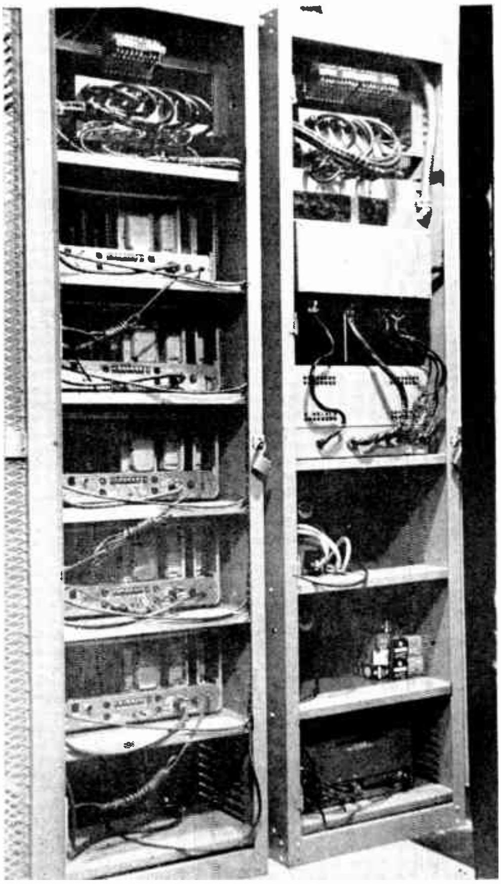


Figure 7. Rear view of cabinets containing the speaker selector, attenuators and amplifiers

Power Compartment

The power compartment in Cabinet 1 contains the fuses, circuit breakers, and power indicating lamps. The amplifiers and boosters (if any) use alternating current, 110 volts, and the speaker selector is supplied with direct current, 110 volts, for the operation of the control circuits. Automatic transfer switches located in the power compartment provide a means for replacing each regular source of power with a stand-by source in the event the regular power fails.

Amplifiers

The amplifiers, one for each microphone group and one spare, are mounted on shelves in Cabinet 2. They are capable of an output of 60 watts of audio power. Each amplifier input and output is connected to a patching panel, located in the top compartment of the cabinet on the left in Figure 7, to expedite the replacement of a faulty amplifier with the spare. A relay has been added to each amplifier to remove plate voltage from the tubes when the amplifier is standing idle. This reduces the heating of the output and power transformers, and eliminates damage to the output transformer caused by the removal of the speaker load. It was found necessary to provide a means of reducing speaker volume for night operation when the office noise level is appreciably less, without changing the amplifier controls. This was accomplished by making use of the second microphone channel with its separate volume control furnished with each amplifier. A switch installed on each amplifier in an accessible location is operated to connect the microphone input to either channel. One volume control is then adjusted for day operation and the second for night operation.

In preparing the public address system for use, it is necessary to adjust the output of each amplifier and attenuator to the correct value. To function properly each amplifier output must be the same since any one may be switched to any speaker group, and if the output levels of the amplifiers differ, the output level of the speaker group would differ with each amplifier connected to it. Each speaker group requires a different amount of power. The amplifiers are adjusted to accommodate the speaker group requiring the most power and the other speaker groups are attenuated the desired amount.

Monitor Microphone, Speaker and Indicator Lamps

A monitor microphone used for maintenance purposes may be connected in the system by means of the 11-contact socket located in the top compartment of Cabinet 2. It is possible to speak from this microphone to any speaker group and at the same time be in a position

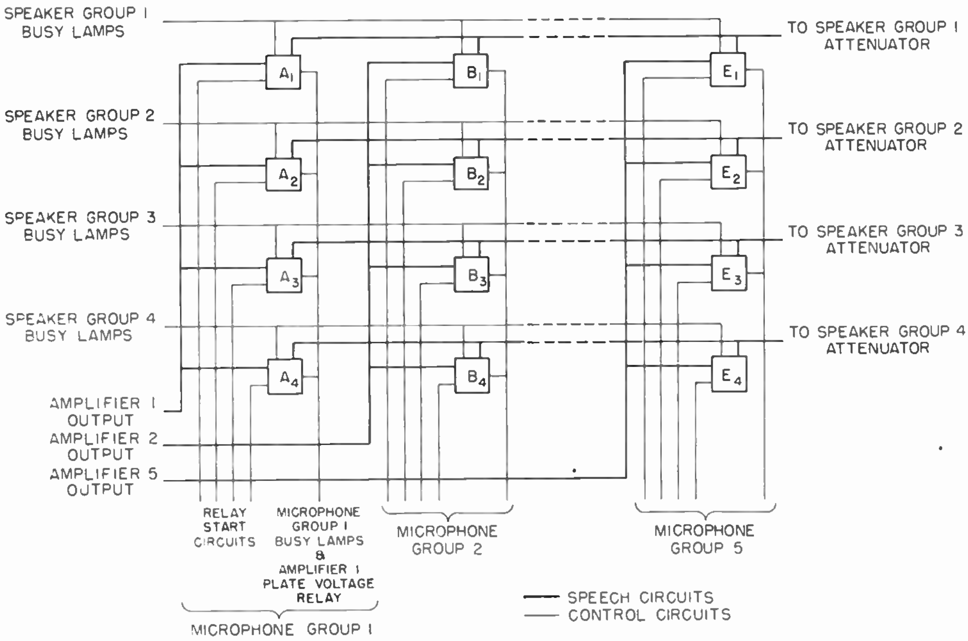


Figure 8. Block diagram of speaker selector showing scheme of operation

to observe the operation of the various components of the cabinets.

The monitor speaker in Cabinet 2 is connected to a selector switch capable of connecting the speaker to the output of any amplifier or to the output of any attenuator.

The indicator lamps next to the monitor speaker in Cabinet 2 indicate busy microphone and speaker groups, and in addition indicate to which amplifiers the microphone groups are connected.

Conclusion

The need for the same type of public address system at all new Western Union reperforator switching centers necessitates the design of equipment which is standard for all centers. This system, therefore, is designed in such a manner that the number of microphones, speaker control boxes, and loud-speakers, varies to conform with the size of a switching center without altering the scheme of operation.

THE AUTHOR: R. W. Good was graduated from New York University in 1941 with a B.S. in Electrical Engineering. During the war he served with the U.S. Army Infantry and Signal Corps. After the war, his Signal Corps unit was detached to the staff of the U.S. Chief of Counsel in Germany, and arranged for the installation of the public address system for the Nuremberg trials. From 1946 to 1948, Mr. Good was employed by the Board of Transportation, N.Y.C., engineering the installation of telephone cables on new construction projects. He joined the staff of the Apparatus Engineer of Western Union in 1948 and has since been engaged in work on intercommunicating systems for the new reperforator switching centers.

A Monitor for the Radio Relay System

R. E. GREENQUIST

SIGNAL CHANNEL reliability is measured primarily by the frequency with which interruptions occur and the duration of the interruptions. The purpose of monitoring a signal channel is to recognize and locate interruptions when they do occur. Monitoring thereby provides a direct means of increasing the reliability of a signal channel by minimizing the time lost while troubles are recognized, located, and corrected.

This article describes a system for monitoring the Western Union microwave radio relay beams which at present provide signal channels between New York and Philadelphia, New York and Pittsburgh, Pittsburgh and Washington, and Washington and New York. The monitor itself is straightforward and so this article concerns itself for the most part with the manner in which the monitoring is accomplished and the information which is derived therefrom.

Proper monitoring of a radio beam must be accomplished by monitoring it completely but entirely apart from associated facilities at the terminals. Thus it is necessary to monitor a characteristic of the radio beam which is representative of satisfactory operation and independent of the operation of associated equipment and the amount of signaling intelligence present. That representative characteristic is the 1-mc subcarrier and the problem resolves itself into one of suitably monitoring it. That the subcarrier is the logical choice can perhaps be more fully appreciated if its function in the radio beam signal channel is reviewed briefly.

The radio beam employs a system of double frequency modulation as is shown in Figure 1. Signaling intelligence over a frequency range of 30 cycles to 150,000 cycles is fed into the modulator at the transmitting terminal. The intelligence frequency modulates a 1-mc subcarrier which is generated in the modulator. The subcarrier, in turn, frequency modulates a carrier, lying in the 3900 to 4200-mc band, which is generated in the transmitter. This signal is fed to the transmitting antenna and beamed to the adjacent relay station.

At each relay station the received signal is mixed with the local rf oscillator, whose frequency lies in the 3900-4200-mc band, and a difference frequency of 32-mc is obtained. This 32-mc if signal is amplified and limited and then demodulated to recover the 1-mc subcarrier. The subcarrier is amplified and then limited to a constant

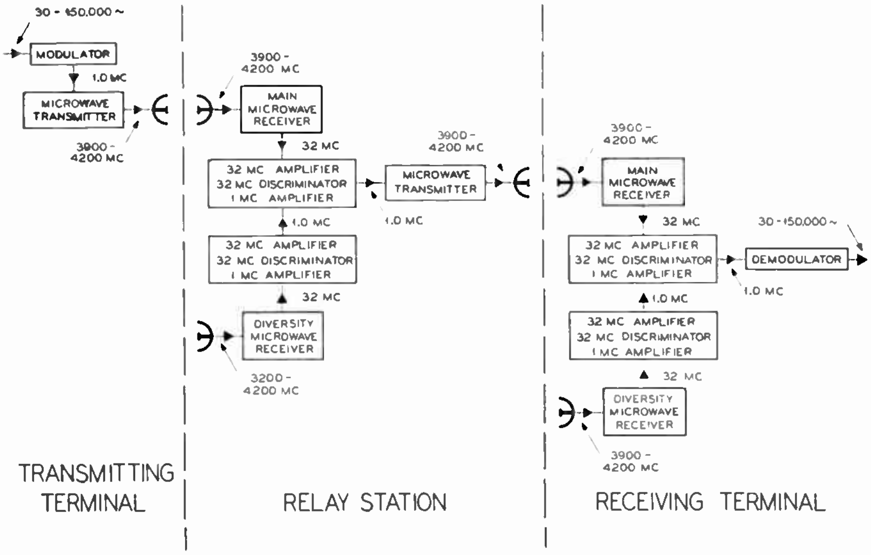


Figure 1. Block diagram of FM radio relay system

specified level. Then it is coupled to the rf circuit of the transmitter where it modulates the carrier, lying in the 3900-4200-mc band, which is generated in the transmitter. The carrier signal is then beamed on to the next adjacent relay station where the same process is repeated. Note that the subcarrier is limited to a constant specified level at each relay station so that the signal transmitted at each station is at the same level though the received signal may be varying. This is true as long as there is enough received signal over each relay path to provide limiting of the subcarrier.

At the receiving terminal the received signal goes through the same procedure as at a relay station until the subcarrier is recovered. Here, however, the subcarrier is amplified and fed to the demodulator where it is demodulated and the original signaling intelligence is recovered.

The foregoing discussion suggests the approach to the problem, namely, use a single frequency signal to modulate the subcarrier and employ this signal at the receiving terminal to operate such indicating devices as are necessary. The received monitoring signal can then be recovered at a constant level as long as limiting is taking place. Since this is an FM system, the discriminator output deteriorates rapidly when limiting action is no longer present, resulting in the loss of the monitoring signal with noise filling its place in the channel. The "noise level" received is dependent primarily upon where in the signal channel the subcarrier is lost. Thus, if a break occurs at the transmitter, the noise introduced will receive maximum amplification and, conversely, noise introduced at the relay stations and receiver will receive correspondingly less amplification. Location of breaks by observation of the noise level is therefore possible.

The Western Union microwave radio relay system for which the monitor was designed is described by Messrs. Corwith and Sullinger in their article, "Western Union's Microwave Relay System", which appeared in the REVIEW for July 1948. Figure 1 was taken from that article.

A monitor was constructed, as shown in Figure 2, with an independent transmitting and receiving section. Then, with a monitor located at each terminal of a radio beam, each direction of the beam can be monitored independently using the transmitting section of one monitor in conjunction with the receiving section of the monitor located at the other terminal. A block diagram indicating the position of the monitors, with respect to the carrier system terminal equipment and the radio beam, is shown in Figure 3.

The components making up a monitor are shown in block diagram form in Figure 4. The transmitting section of the

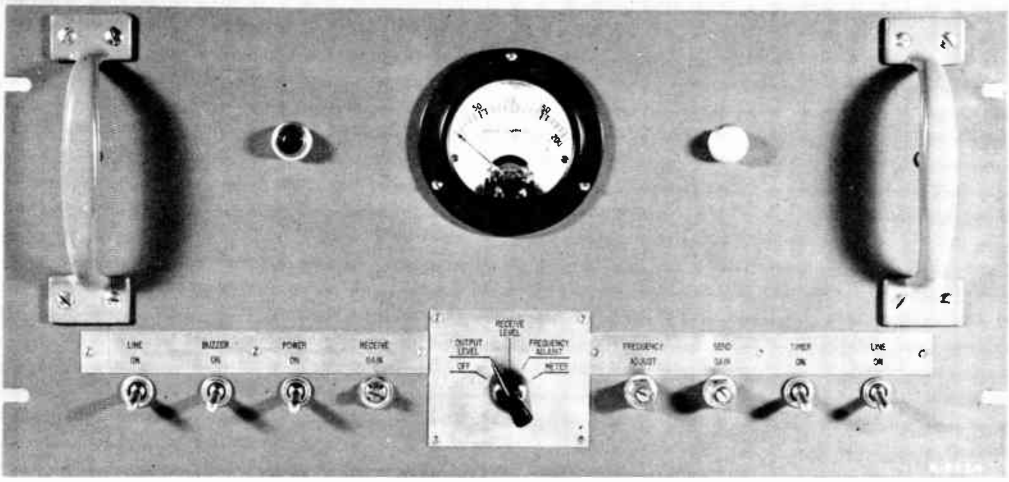


Figure 2. Monitor for radio relay system

monitor consists of a phase-shift oscillator followed by two stages of amplification. The output of the amplifier is filtered by a very narrow band-pass filter and then transformer-coupled, to give a balanced output, to the radio beam modulator input. The frequency of the monitoring signal was chosen to be 90 cycles so that there would be no interference with the carrier system frequencies which carry the signaling intelligence and which extend from 150,000 cycles down to 300 cycles. The level at which the monitoring signal is fed into the modulator is approximately —18 dbm which is 6 db below the level of a single telegraph channel on the radio beam. This level is low enough so that no appreciable loading is caused by the monitoring signal. Since the monitor output and carrier system output are in parallel at the input to the modulator, the filter in the output circuit of the monitor is designed to have a very high impedance over the range of the carrier system frequencies.

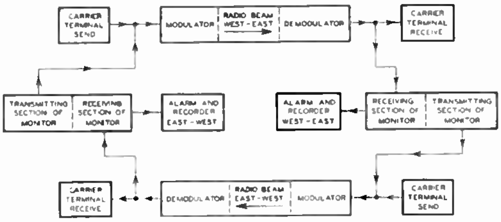


Figure 3. Block diagram of monitors in relation to radio beam and carrier terminal equipment

The receiving section of the monitor consists of a stage of selective amplification employing a bridged-T inverse-feedback network followed by two additional stages of amplification, a narrow band-pass filter, and a bridge-type rectifier. The output of the radio beam demodulator is transformer-coupled to the selective input stage of the receiver, and inasmuch as the monitor receiver is in parallel with the carrier system terminal equipment, the input circuit of the receiver is designed to present a high impedance over the carrier system frequency range. The monitor, therefore, has no effect on the operation of the carrier system equipment. The received monitoring signal thus is amplified, filtered, and rectified, and the rectified signal is used to operate the alarm system.

The alarm system consists of an undercurrent relay which operates a neon light and a buzzer connected in parallel. The relay is adjusted to actuate the neon light and the buzzer when the rectifying monitoring signal drops below a specified level. Independently of the alarm system, a graphic recorder shows the level of the received monitoring signal and, in the absence of a signal, it records the level of the noise which passes through the receiver filters.

The graphic record produced by the monitor during a test on a radio beam with three relay stations is shown in Figure 5. Time runs from right to left on the chart and the record is discussed in that order. The first section of the chart record shows the normal received level of the monitoring signal and the level at which the alarm system is set to operate. Following are the records produced by a break at the transmitting terminal, a break at each of the relay stations in succession, and finally a break at the receiving terminal. The average "noise level" of the record produced by each break is indicated on the chart. However, it must be kept in mind that this is not a true noise level because the noise recorded by the monitor lies in a very narrow pass band.

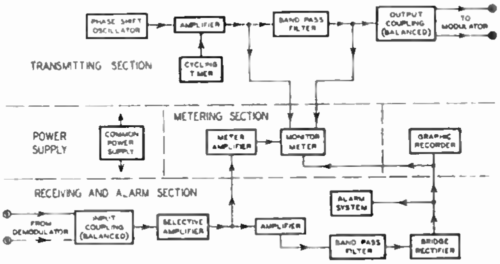


Figure 4. Block diagram of monitor

Following the record so far discussed is a record produced by alternately killing the monitoring signal for 5-minute periods. This is accomplished by a timing motor which operates a microswitch in the filament circuit of the amplifier in the transmitting section of the monitor. This cycling operation may be used at the option of the personnel in charge of the monitor.

The purpose of the cycling record is to provide periods when the monitor "listens" for noise. Thus, if a beam is suspected of being noisy, it may be advisable to select this type of monitoring to obtain a graphic record of the "noise level." During this type of operation, however, the alarm system must be disabled thus nullifying the primary function of the monitor.

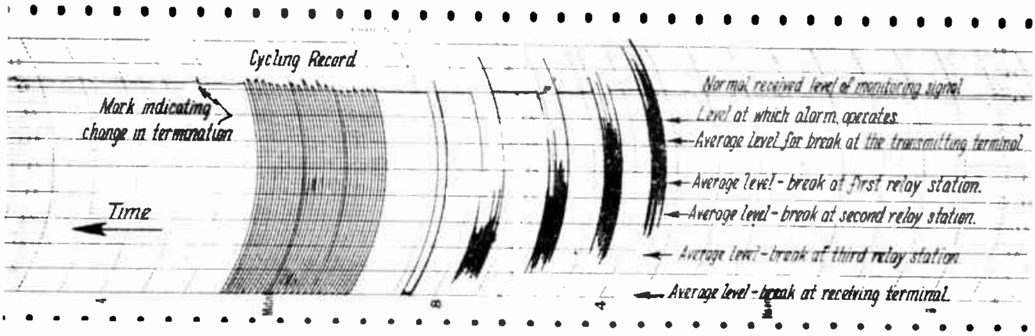


Figure 5. Radio beam monitor record

The small "pip" near the end of the record is introduced when the incoming monitoring signal at the receiving terminal sees a change in the carrier system termination. Normally the carrier system termination is 125 ohms but, during switching operations, the carrier system terminal momentarily presents an open circuit, hence infinite impedance. The result is a momentary rise in the level received by the monitor since its input circuit is in parallel with the carrier system input. Therefore, a "pip" shows on the graphic record whenever a switching operation is performed at the carrier system terminal.

The monitor is not intended to replace monitoring facilities already available on the radio beam or in the carrier system terminal equipment. It is intended that the monitor supplement these other monitoring facilities since it provides information not otherwise available and it provides this information audibly and graphically. Two unique and complementary functions are provided by the monitor when it is applied to a radio beam, namely, warning and recording. Immediate warning by the monitor gives maintenance and operating personnel valuable assistance in their efforts to provide more efficient maintenance and operation of a radio beam, thereby increasing its reliability. By graphically recording the performance of the signal channel provided by a radio beam, the monitor makes it possible to evaluate the reliability of the signal channel.

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THE AUTHOR: R. E. Greenquist was attending Northeastern University and was employed by the Allis-Chalmers Manufacturing Company, as a student engineer, when the war interrupted his studies in 1942. He served with the Air Force for four years and after separation from the service he transferred to Cornell University. He was graduated from Cornell with a Degree of Bachelor of Electrical Engineering in June 1948. Immediately after graduation, he joined the Radio Research Division of Western Union. Mr. Greenquist participated in microwave propagation tests and in testing and modifying the radio relay system. At present, he is in charge of passive reflector tests being conducted in conjunction with the proposed microwave "pole line" system. He is an associate member of the IRE.

Telecommunications Literature

TRAVELING-WAVE TUBES—J. R. PIERCE—D. Van Nostrand Co., N.Y., 1950. An excellent treatment of the general considerations of traveling-wave tubes. This book is recommended for engineers and mathematicians — E. N. WRIGHT, Ass't Radio Research Engineer.

BASIC TELEVISION, PRINCIPLES AND SERVICING — BERNARD GROB — McGraw-Hill Book Co., Inc., N.Y., 1949. Presents the subject of television in a clear and simplified manner. While it is written largely in nontechnical language and contains little or no mathematics, its scope is so wide that even the design engineer should find it a useful reference book.—O. E. PIERSON, Engineer, Electronics Research Division.

ELECTRICAL ENGINEERS' HANDBOOK — ELECTRIC COMMUNICATION AND ELECTRONICS, Fourth Edition—PENDER AND MCILWAIN—John Wiley and Sons, N.Y., 1950. A new edition of this well-known handbook is now available. Its value as a standard reference source for communications and electronics engineers has been substantially increased by inclusion of a very considerable amount of new material covering advances made in these fields since the third edition was published in 1936. Electron optics, frequency modulation, pulse techniques, wave guides, magnetron and klystron oscillators, and network analysis based on applications of function theory will serve to illustrate the nature and extent of this new subject matter. For the telegraph material, the editors have drawn heavily from the technical writings of Western Union authors, particularly in the section on ocean cables—A. BOGGS, Engineer, Transmission Research Division.

ELECTRONS AND HOLES IN SEMICONDUCTORS—WILLIAM SHOCKLEY, Ph.D.—D. Van Nostrand Co., N.Y., 1950. This book provides the first comprehensive treatment of transistor devices for students as well as for the more advanced reader. "Transistor Electronics" is developed by the concept of the positive pole, or deficit produced by the removal of valence electrons from the lattice structure, and its negative counterpart, the excess electron. The book is divided into three parts. In Part I only the simplest theoretical concepts and experimental results are introduced to provide a working knowledge of transistor devices for electrical engineers or undergraduate students not possessing an understanding of quantum theory and wave mechanics. Part II presents the physics of semiconductors and discusses electrical engineering analogues which serve as a bridge of understanding between the more elementary presentation of Part I and the abstractions which follow. In Part III the more difficult topic of quantum-mechanical principles is discussed which leads to the abstractions of holes and electrons from fundamental quantum theory. Two introductory chapters are provided in this section in order to make the spirit of these mathematical investigations more accessible to readers without extensive training in theoretical physics.—W. D. CANNON, Engineer, Transmission Research Division.


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