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GENERAL PRINCIPLES OF TELEGRAPH OPERATION

TELEGRAPH SYSTEMS

1. General.

The transmission of intelligence by means of the standard telegraph systems used by the Bell System is accomplished by setting up a flow of electric energy in a circuit and interrupting or reversing the current in accordance with the signaling code used. The simplest form of telegraph circuit possible is that composed of a relay or sounder at one end in series with a line wire and a battery, and having a key at the other end, the circuit being completed by connecting at both ends to ground. The closing of the key will then permit current to flow in the circuit, operating the relay or sounder to the closed or "marking" position. The opening of the key will stop the current flow, causing the armature of the relay or sounder to move to the open or "spacing" position. The terms "marking" and "spacing" have persisted from the time when telegraph signals were received by recording upon a tape.

A circuit such as that described above, extending for only a short distance, will have negligible inductance, capacity and leakage in the line, and for all practical purposes the line may be considered as containing pure resistance only. The current wave resulting from opening and closing the key periodically will, therefore, be approximately a rectangular wave if the inductance of the relay or sounder is relatively small and the resistance of the circuit relatively high. However, telegraph circuits are usually comparatively long and have material amounts of inductance and capacity as well as resistance; also the equipment used in telegraph systems and the arrangements for superposing the telegraph on telephone circuits have inductance, capacity and resistance. These properties so affect the telegraph currents that their wave-forms are no longer rectangular, hence they can not be regarded as simple direct-current impulses. It is necessary, therefore, to apply alternating-current and transient-current theories in considerations of telegraph problems.

Viewed as an alternating current rather than an interrupted direct current, the rectangular wave of the simple telegraph circuit when a long succession of uniform "dots" and "spaces" is transmitted may be considered as composed of an infinite number of sinusoidal waves plus an uninterrupted direct-current component. The sinusoidal waves consist of the fundamental and a complete series of odd harmonics, the third harmonic having one-third the amplitude of the fundamental, the fifth harmonic one-fifth the amplitude and so on. For illustration, the fundamental and third and fifth harmonics of one of a succession of dots is shown in Figure 1. To simplify the drawing, harmonics above the fifth are omitted.

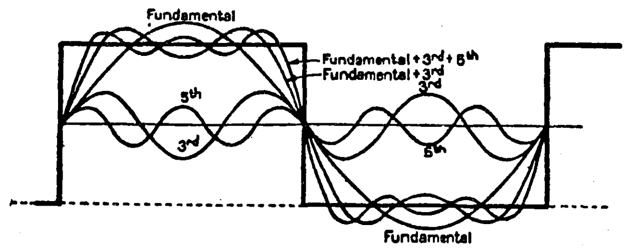

Fig. 1.—Harmonics in Rectangular Wave.

When miscellaneous signals are sent, as in actual operation, it is of course not correct to refer to the waves of the dot-frequency and its multiples as the fundamental and harmonics. In order to simplify the consideration of the operating speed of telegraph circuits, it is, however, customary in practice to consider the speed of signals transmitted over a circuit as the dot-frequency. Thus fast hand-speed signals are rated at about 12–15 dots per second, while start-stop printer signals at 360 operations per minute are rated at 23 dots per second.

If all the harmonics of the signal wave were transmitted with the same attenuation and at the same speed, the wave-shape at the receiving device would be the same as that at the transmitting device. Similarly, the more harmonics that are transmitted, the more the received wave will resemble the transmitted wave and the receiving device can the more easily reproduce undistorted signals. In "direct-current" telegraph circuits it is necessary to transmit all the frequencies from practically zero to a frequency greater than the dot-frequency. By using sufficiently refined and probably expensive receiving devices, intelligence may be satisfactorily conveyed by means of waves containing frequencies exceeding the dot-frequency by only a slight amount. Such refined and expensive receiving equipment is justified when the line circuit is costly, so that it pays to push its transmission possibilities to the utmost. A transatlantic submarine telegraph cable, costing several million dollars, is a case in point. In connection with the lines of the Bell System, however, such refinement of the receiving apparatus is not usually justified, so that the speed is not ordinarily pushed beyond the point where the third harmonic of the dotting speed is partially suppressed.

The current transmitted over the telegraph circuits (other than carrier circuits) in the Bell System contains frequency components from zero cycles (direct current) up to about 80 cycles per second. The telephone circuits on the same wires transmit frequency components from about 200 cycles per second upward.

The impedance of a circuit which has large attenuation does not change appreciably with a change in the termination at the distant end, because the attenuation of the circuit reduces distant reflection effects to a negligible amount, while the impedance of a circuit which has small attenuation will be materially affected by such a change. On the average telephone repeater section the attenuation is relatively large, while on the average "direct-current" telegraph repeater section there is comparatively little attenuation. The terminal apparatus on most telephone repeater sections thus reacts less on the transmission over the circuit than the terminal apparatus on a "direct-current" telegraph repeater section of average length. Because of this, the impedance of a telephone circuit may be simulated closely throughout the voice range and through varying weather conditions by a comparatively simple network, thus facilitating telephone repeater operation with balancing networks. On the other hand, a fixed network which will balance a "direct-current" telegraph circuit and the equipment at the distant end under certain weather conditions will not balance the same layout accurately under other conditions of temperature and leakage. For this reason the maintenance of a proper working balance on a polar duplex telegraph circuit requires an adjustable network which must be readjusted from time to time.

A current wave which is rectangular, or approximately so, will operate the relay or sounder in a quick and "snappy" manner with a minimum tendency towards distortion due to variations in current strength, relay adjustment, etc. Such a wave, however, if transmitted over a telegraph line, would cause severe "crossfire" or telegraph interference in adjacent telegraph circuits. In practice series inductance, alone or in combination with bridged capacity, is inserted at the transmitting end in order to eliminate the higher harmonics in the telegraph signals or, in other words, to "round off" the signal waves. A rectangular current wave would also be objectionable when the telegraph circuit is superposed upon a telephone circuit, since the higher frequencies in the signal wave would cause serious noise or "telegraph thump" in the telephone circuit. When a telegraph circuit is obtained by simplexing a telephone circuit which is properly balanced from the standpoint of noise, telegraph thump will not be caused in the telephone circuit if the telegraph signals are rounded off as noted above. In the case of telegraph circuits obtained by compositing a telephone circuit, additional series inductance and bridged capacity contained in the composite set itself serves to reduce telegraph interference in the telephone circuit.

2. Quality of Telegraph Transmission.

In telegraph transmission the volume of the sound caused by the operation of the receiving sounder depends only upon the current in the local circuit in which the sounder is located, and the adjustment of the sounder itself. Variation in operating current beyond normal working limits in some part of the circuit between the sending and receiving stations will manifest itself by a change not in the volume but in the distortion of the received signals. The volume of the sound caused by the receiving sounder is therefore a relatively unimportant factor in the quality of telegraph transmission and distortion alone is to be considered. This is in contrast with telephone transmission, where the received volume is an important consideration.

If a signal made up of a given number of dots and dashes and spaces is transmitted, the individual pulses as reproduced on the receiving sounder will not in general be exactly equal in length to the corresponding pulses as they leave the sending end, but will be shorter or longer. If each time a given signal combination is sent the same distortion effects are noted the distortion is said to be *systematic*. If, however, the distortion effects are variable from signal to signal the distortion is said to be *fortuitous*. The impairment of signals normally observed is caused by a combination of systematic and fortuitous distortion.

Under the heading of fortuitous distortion comes that caused by inductive interference, crossfire and duplex unbalance. With each of these the time at which any interfering pulse will occur and also its magnitude are unpredictable, so that its effect (and consequently the magnitude of the distortion it causes) depends upon the phase and strength of the interfering current in comparison with the signal current.

Systematic distortion may be divided into two classes—*bias* and *characteristic distortion.* Under bias comes that part of the distortion resulting from improper adjustment of relays, unequal battery potentials, steady duplex unbalance currents, earth potential differences and leakage currents. Bias makes signals unsymmetrical, affecting marking and spacing signals in opposite ways. It may uniformly lengthen all marking signals and correspondingly shorten all spacing signals in which case it is known as marking or positive bias, or it may have the opposite effect, shortening all marking signals and lengthening all spacing signals, in which case it is known as spacing or negative bias. The term, "Characteristic distortion," is used to describe that part of the distortion which is peculiar to a given pulse of a given signal combination resulting from the particular electrical characteristics of the system and the magnetic and mechanical characteristics of the relays used. It is thus dependent upon the type of line facilities involved, the length of the repeater sections and the type of apparatus in the circuit. It is a symmetrical distortion, since it affects similarly placed marking or spacing signals in a similar manner. For this reason it is distinguished from bias, mentioned above.

With a given telegraph circuit the effect of characteristic distortion upon any given impulse is dependent upon the signals immediately preceding it, for example, the effect upon a marking signal when it has been preceded by a long spacing signal will be different from the effect when it has been preceded by several short marking and spacing signals (dots and spaces). For instance, the American Morse letter "C," accurately sent by means of a commutator, is frequently used in telegraph testing work since the signal combinations in it are such as to be considerably affected by characteristic distortion. As sent by a commutator, the letter consists of a marking signal of unit length, a spacing signal of unit length, a marking signal of unit length, a spacing signal of twice unit length, a marking signal of unit length and a spacing signal of four times unit length (see Figure 2).

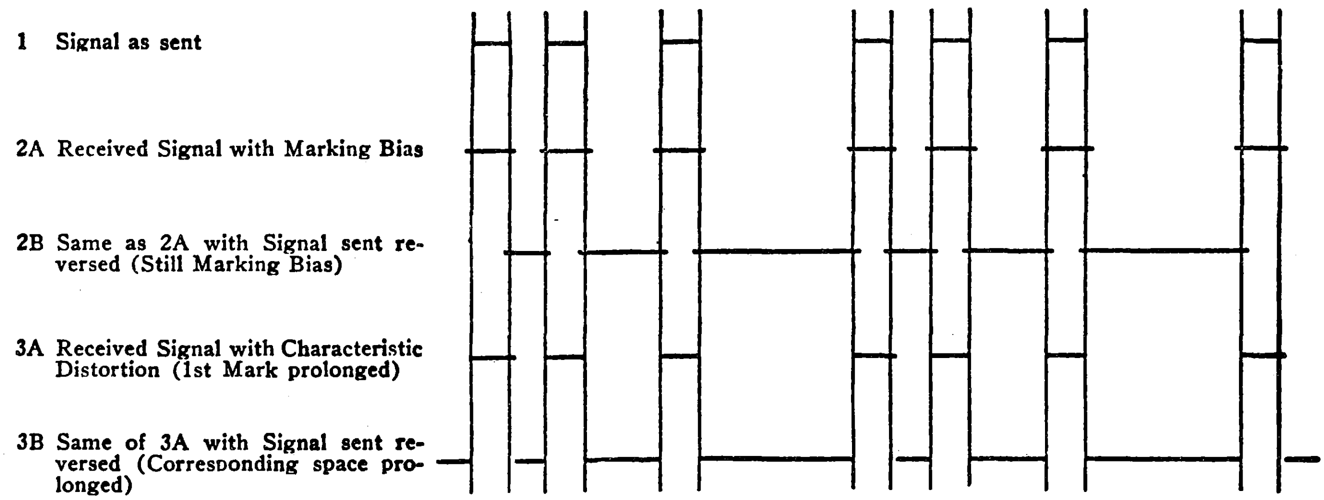

Fig. 2.—Effect of Bias and of Characteristic Distortion Upon a "C" Signal.

Figure 2 shows how the pulses of the Morse letter "C" may be affected by bias and characteristic distortion.

Investigations indicate that of the bias and characteristic distortion of signals passing over a given circuit, the characteristic distortion is usually practically constant from day to day, depending on the make-up of the line circuit and the apparatus involved. The bias, however, is a variable factor, changing even from hour to hour and depending as stated above upon the adjustment of apparatus the battery potentials, earth currents, insulation, etc.

3. Systems and Apparatus Used.

Either of two methods of operation may, in general, be used in connection with the telegraph service given by the Bell System. In one, messages are transmitted over the circuit in the two directions interchangeably, the stations passing information back and forth in much the same manner as two persons talking over a telephone circuit. The circuit may have stations at the terminals only or may have intermediate stations. With this type of service, which is known as "singled" service, one two-way circuit is required and provision must be made so that any station on the circuit can "break" or interrupt the entire circuit by opening the key at that station. In the other method of operation, information is passed simultaneously in both directions, two independent one-way channels being provided. This type of service is known as "duplexed" service. Duplexed circuits seldom have intermediate stations, because of the difficulty from a traffic standpoint in operating intermediate stations. The "break" feature is not required, any question raised by a receiving operator being passed to the other station by means of a key in the associated sending circuit.

The various standard telegraph systems are discussed briefly below. Of these the Neutral and Two-way Non-duplex Polar Telegraph systems provide only singled service, while the others provide either singled or duplexed service as desired.

Schematic drawings illustrating the salient features of the line circuit arrangements of each of the standard telegraph systems are given below. Where singled service is given, the subscriber is provided with one loop at each station which is used for both sending and receiving. Where duplexed service is given, two separate loops are provided, one being used solely for sending and the other solely for receiving. The feasibility of changing at will from singled to duplexed service by rearrangement of the terminal equipment requires that the actual transmission over the line shall be by means of separate and distinct channels for each direction at all times.

Two types of relays and sounders are in common use in the telegraph service of the Bell System—neutral and polarized.

When the electromagnet of a neutral relay or sounder is energized, its attraction for the armature of the relay overpowers the opposing force of a spring and so pulls the armature to its closed or "marking" position; when the electromagnet is de-energized, the armature is pulled to the open or "spacing" position by the spring. A neutral relay or sounder operates when the magnet overpowers the spring regardless of the direction of the operating current flowing through the magnet windings.

In polarized relays, or sounders, on the other hand, the polarity of the operating current determines whether the armature will be removed to the marking or the spacing side. A polarized relay or sounder is provided with a steady magnetizing force obtained either from a permanent magnet or from an extra winding which acts in conjunction with the flux generated by the current in the operating windings to make the relay or sounder operate selectively on currents of positive and negative sign.

3.1 Neutral Telegraph System.

The simplest telegraph system in common use is the Neutral (open and close) system in which signals are produced by the opening and closing of a direct current circuit. Neutral relays are used throughout for receiving. To obtain the best transmission, a battery is usually located at each end of the circuit, the two batteries being opposite in polarity, although in many cases a battery at one end only will give satisfactory results.

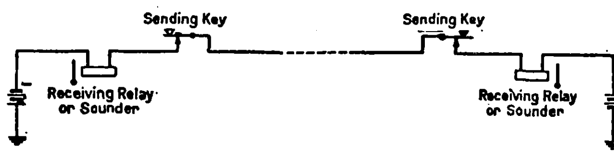

Fig. 3.—Line Circuit Arrangement, Neutral Telegraph System.

The Neutral system is used by the telephone companies for most local circuits and for the shorter line circuits operated either manually or with printers. (The term "manually" is intended to include signals produced by means of a semi-automatic key.) It is a very flexible arrangement since additional sending and receiving apparatus can be readily connected in series in the telegraph circuit at any point. It is not well adapted for use on long circuits or on circuits having considerable leakage as a result of wet weather.

For the shorter circuits good transmission can be obtained between stations at the ends of the line without intermediate apparatus. On the longer circuits, repeaters are located at the telegraph repeater points nearest to the subscribers' stations or in the main line between subscribers' stations and the circuits are operated through these repeaters.

3.2 Bridge Polar Duplex Telegraph System.

The Bridge Polar Duplex system is extensively used on the open-wire lines of the Bell System although it is no longer standard. It may be used for either manual or printer operation. With this arrangement the line circuit is operated on a polar basis, that is, positive and negative batteries are connected to the line at each end for the spacing and marking impulses respectively and a polarized relay is used for receiving. A balanced arrangement is provided at each end of the circuit, using an artificial line to balance the line and apparatus at the distant end, so that the two ends of the circuit may send interchangeably, or if desired simultaneously.

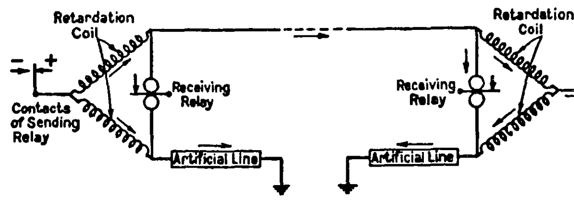

Fig. 4.—Line Circuit Arrangement, Bridge Polar Duplex Telegraph System. (Note. In practice, transmitting battery is applied to the apex of both duplex sets.)

Since the impedances of the two bridge arms are equal, if the artificial line accurately balances the real line together with the apparatus at the distant end, the receiving relay at the left will not be operated by signals sent from the left end, for this relay is then connected across points between which no potential exists due to these signals. The relay at the left, however, will be operated by signals sent from the right end of the circuit. Similarly the relay at the right will be unaffected by signals transmitted from the right end but will be operated by signals transmitted from the left.

The telegraph transmission over a circuit where the transmitting is done by reversing the polarity of the battery connected to the line and polarized relays are used is much more satisfactory than over those circuits operated by the Neutral or open-and-close system with neutral relays. The benefit of the reverse battery transmission results from the fact that the signals operating the receiving relay are symmetrical, that is, the building-up and falling-off of the current occur in the same manner. In the case of the Neutral system the current may build up and fall off with entirely different wave shapes, depending upon the electrical characteristics of the circuit. For example, a short Neutral circuit having series inductance and no bridged capacity or spark-killers on the key contacts will have a wave which builds up slowly when the key is closed and falls off abruptly when the key is opened. A long circuit having a large bridged capacity will have a wave which builds up slowly when the key is closed and decays much more slowly when the key is opened.

Furthermore, with the symmetrical current wave obtained in polar operation the signals do not become biased when the electrical characteristics of the circuit are changed. That is, relays may be added, the current may change or the leakage effect may change without biasing the received signals or materially reducing the operating margin. In the case of the Neutral circuit, however, any of the changes mentioned above will change the bias condition of the received signals and leakage will more seriously affect the operating margin. Polar transmission has other advantages over Neutral transmission, notably that polarized relays are more sensitive and may be more accurately adjusted than neutral relays.

3.3 Differential Duplex Telegraph System.

An arrangement of the polar duplex method of operation known as the Differential Duplex telegraph system is now standard for use in grounded operation on open-wire lines or in cable.

If, instead of the arrangement shown in Figure 4, the arrangement shown in Figure 5 with differential polar relays is used, signals sent from the left end of the circuit will not operate the receiving relay at the left, when the artificial line balances the real line together with the apparatus at the distant end. This is true because the impedance of the path from the sending contacts through one relay winding to the line and thence to ground through the apparatus at the right being equal to the impedance of the path through the other winding of the relay and the artificial line to ground, equal currents will flow in these paths and the relay will not be operated because the currents are flowing through the relay windings in parallel opposing. Signals sent from the right end however, will operate the receiving relay at the left, therefore each relay operates independently of the other.

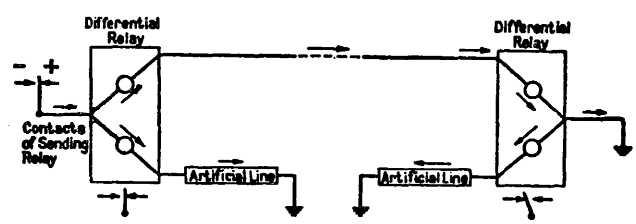

Fig. 5.—Line Circuit Arrangement, Using Differential Relays and Ground Return.

3.4 High-Frequency Carrier Telegraph System.

The high-frequency carrier telegraph system is normally used to provide additional facilities on open wire lines when all of the circuits which can be obtained by compositing are in use. In a "Type B" carrier telegraph system any number of two-way circuits up to ten can be provided on one nonloaded open-wire metallic circuit. In each circuit current of a frequency above the voice range is obtained from a vacuum-tube oscillator and is controlled by a local circuit so that pulses of high-frequency current corresponding in duration to the marking impulses are sent over the line in common with those of other circuits. At the receiving end the high-frequency currents are separated by tuned circuits and, after being amplified and rectified, control the local circuits associated with their respective circuits.

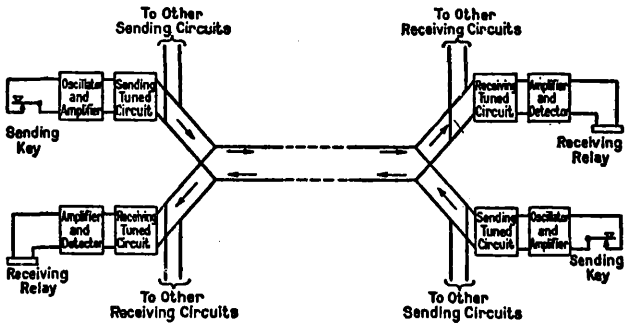

Fig. 6.—Line Circuit Arrangement, High-Frequency Carrier Telegraph System.

Discrimination between the sent and received signals is obtained by using (in the Type B systems) a frequency range from 3300 to 5500 cycles for transmission in one direction and a range from 6500 to 10,000 cycles for transmission in the opposite direction. Since a balanced circuit arrangement, such as is used in the polar duplex systems, is not employed, the quality of duplexed transmission does not depend upon the maintenance of an accurate balance, and duplexed transmission of a high standard is obtained.

3.5 D-C. Metallic Telegraph System.

The metallic telegraph system is used to provide telegraph circuits in small-gauge cable. Small currents are used on the line circuit, polar transmission and sensitive relays being employed. A balanced arrangement is provided so that messages can, if desired, be sent simultaneously in both directions. The receiving relays are connected differentially in the circuit, instead of across two bridge arms as in the Bridge Polar Duplex system.

Because of the limitations in operating telegraph circuits over composited facilities in long toll cables, it is necessary to employ relatively small line current and line battery of relatively low voltage. Metallic circuits are used in order to eliminate interference from ground potentials and crossfire and also from power circuits. The line circuit arrangement is shown below in Figure 7.

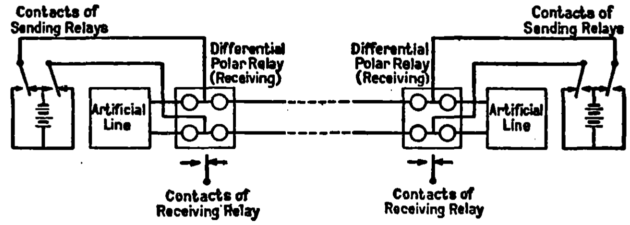

Fig. 7.—Line Circuit Arrangement, Metallic Telegraph System.

3.6 Two-Way Non-Duplex Polar Telegraph System.

This system is used to provide facilities for printer operation from telegraph repeater stations to outlying points too distant for operation on local or loop circuits from the repeater station. It is designed primarily for use on open wire circuits, but can be used on short sections of large gauge cable. The line circuit in this system is arranged as a one-way circuit with polar transmission, a special feature being the provision for reversing at will the direction of transmission over the circuit. Two types of sets are available in this system, the central office set and the substation set. The local circuit or loop in the central office set is arranged as in the carrier and metallic telegraph systems, the necessary equipment being located at the repeater office, while the equipment making up the substation set is located on or near the printer table at the subscriber's office. A circuit having only two printer stations may be operated by using a substation set at each printer station. If a repeater is required, two central-office sets may be connected together by means of their loop circuits. Since polar transmission is employed and there is no duplex balance to be maintained, the two-way non-duplex polar telegraph system gives satisfactory results.

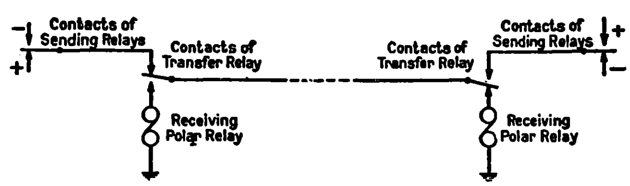

Fig. 8.—Line Circuit Arrangement, Two-Way Non-Duplex Polar Telegraph System. Transfer Relays operated for sending from left to right.

3.7 One-Way Polar Telegraph System.

This system is used for providing one-way service with printers mainly over short distances. The quality of transmission with this system is very good and the application of this arrangement is limited only because of the more general requirement for two-way service. In the one-way polar telegraph system signals are sent into one or more circuits by pole-changing relays controlled by a local circuit. These signals operate polarized relays in the line circuit which is connected directly to ground at the distant end.

3.8 Voice-Frequency Carrier Telegraph System.

The voice-frequency carrier telegraph system normally uses for its line facilities a four-wire cable telephone circuit, the circuit being assigned wholly to the telegraph system. As many as ten or twelve circuits are obtained by using frequencies within the voice range furnished by a special generator; a single generator being capable of caring for several systems. The east-bound path of the four-wire circuit is used for transmission in one direction and the west-bound path for transmission in the other direction, the same frequencies being employed in each case. Except for the method of discrimination between transmission in the two directions, the operation of the voice-frequency carrier telegraph system is similar to that of the high-frequency carrier telegraph system. Since no duplex balance is involved, duplexed service over any given facilities will be of the same grade as singled service over the same facilities.

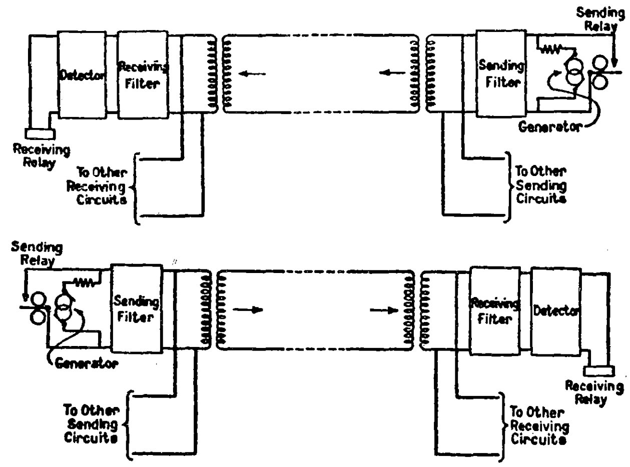

Fig. 9.—Line Circuit Arrangement, Voice-Frequency Carrier Telegraph System.

COORDINATION WITH THE TELEPHONE

4.0 General.

This section covers the points which must be considered when two services are as closely associated as are the telephone and telegraph services in the plant of the Bell System. In some cases the telegraph channels occupy exclusively the conductors involved, as for instance, over very short distances with the grounded telegraph systems and over long distances with the voice-frequency telegraph system. In the remainder of the Bell System telegraph services the telegraph channel is superposed upon the telephone channel.

The reactions of telegraph service upon telephone service which most frequently come to the engineer's attention are those involving grounded telegraph service superposed upon the telephone circuits. These reactions are in the form of three effects:

(1) Telegraph Thump
(2) Telegraph Flutter
(3) Telephone transmission losses in telegraph apparatus.

The metallic and high frequency carrier telegraph systems do not normally cause objectionable thump or flutter in the telephone circuit.

Telegraph is not superposed on certain types of high grade facilities such as picture transmission and program supply circuits.

5.0 Telegraph Thump.

The maximum dot-frequencies of the telegraph signals used in Bell System service are inaudible in the telephone receiver. The higher harmonics of the maximum dot-frequencies employed are, however, well up into the audible range and will consequently be heard as noise if an appreciable amount of energy at these frequencies reaches the telephone receiver. The noise caused by these higher-frequency currents is known as "telegraph thump."

Telegraph thump is rarely caused on adjacent circuits by telegraph operation over short distances on conductors used solely for telegraph purposes. In cases where thump is reported in the local plant caused by telegraph operation over conductors in the same cable, for instance, it will frequently be found that the difficulty is due to the operation of services such as ticker service which employ higher frequencies than those used in standard Bell System service. Telephone typewriter installations made in accordance with the standard installation plans should not cause noticeable thump except

under unusual conditions. Thump due to telegraph operation in the local cable plant should be investigated to determine whether unusual unbalance conditions exist and whether the circuit is being operated without adequate noise-killers.

In the case of telegraph circuits superposed upon toll telephone circuits by either the composite or simplex methods, telegraph thump may sometimes be clearly audible at the testboard. Telegraph currents of the frequencies heard at the testboard are usually considerably attenuated in reaching the subscriber station, and listening tests to determine the presence of thump should, therefore, be made at the subscriber station. In running down a case of difficulty from thump, listening at the testboard position will frequently be of assistance in determining the cause of the trouble. Tests made in connection with a survey of the toll plant for telegraph thump should be made at a typical subscriber station rather than at the testboard. Some of the earlier arrangements of the monitoring connection of the telephone set at the testboard and some of the service observing circuits tend to accentuate the audibility of thump currents.

If the noise due to the higher frequencies of the telegraph currents is in any case so great as to be objectionable at the end of the subscriber loop, it indicates something irregular in the line equipment, the telegraph equipment or the line. In a composited circuit, this irregularity may be one or more of the following:

(1) An open circuit in the grounded condenser branch in the telegraph legs of the composite set.
(2) A leak in the series condensers in the telephone branch of the composite set.
(3) An open circuit in the crossfire branch of the composite set.
(4) The application of telegraph signals to the telegraph leg of the composite set without sufficient noise-killer in the circuit, or the use of a defective noise-killer.

In a simplexed circuit, the irregularities which may cause objectionable telegraph thump are as follows:

(1) Unbalance in the line wires
(2) Unbalance in the simplex coils
(3) Application of the telegraph signals to the telegraph leg without sufficient noise-killer or with defective noise-killer.

The presence of telegraph thump may frequently be reported when the difficulty is actually due to false operation of the signaling relay in the composite ringer. Low frequency impulses of the dot-frequency or its second or third harmonics pass through the series condensers in the telephone branch of the composite set and are modulated due to the core material of the phantom repeating coil. This modulation effect may produce frequencies in the neighborhood of 135 cycles for which the signaling relay is most sensitive. In some cases this tripping of the ringer may be severe enough to cause a steady ring which could easily be diagnosed as ringer trouble. In other cases, tripping of the signaling relay may produce clicks which appear to follow the telegraph signals and which are frequently thought to be telegraph thump. It is important that trouble caused by tripping off of the signaling relay should be clearly distinguished from telegraph thump.

Noise at the subscriber station caused by tripping off of ringers may be obviated by more careful adjustment of the signaling relay or by any measure which reduces modulation in the phantom repeating coil or increases the attenuation of the lower frequencies in the telephone branch of the circuit. Care must be taken that the measures employed do not cause serious transmission loss in the telephone circuit or the telegraph circuit. Coils have been designed so as to be more stable than the other types of phantom repeating coils and the impulses which tend to operate the signaling relay are thereby minimized. In addition to using these coils the capacity of the condenser at the center of the drop side of the phantom repeating coil may be reduced, in cases in which particularly severe interference is being produced. This condenser can usually be reduced to one microfarad without causing serious transmission loss in the telephone circuit.

The standard polar duplex systems are arranged so that the signals applied to the telegraph leg of the composite or simplex set will seldom contain sufficient of the higher frequency components to produce objectionable telegraph thump if the line and line equipment are normal. The one-way polar telegraph system is arranged with a noise-killer which is normally effective in preventing telegraph thump. The use of a potentiometer arrangement which reduces the potential applied to the line circuit is also effective in preventing telegraph thump with the one-way polar system. In other forms of telegraph operation which may be used on our circuits, it may be found necessary with different types of grounded telegraph systems to insert special forms of noise-killer in the telegraph circuit in order to reduce the amount of telegraph thump.

The telegraph thump at the point where telegraph signals are applied to the line is usually more severe than at the distant end of the circuit since the higher frequencies of the telegraph current which are most audible in the telephone receiver are attenuated in travelling down the line. The receiving relay may also generate noticeable thump in certain cases because of the inductive kick in the relay windings caused by the travel of the relay armature through the magnetic field surrounding it.

The connection of a telegraph circuit obtained by simplexing to one obtained by compositing may occasion thump in cases where the simplexed circuit is short and contains little capacity to ground. The telegraph signals traverse the simplexed circuit and reach the intermediate composite set on the composited circuit with little "rounding-off" so that the condition is not unlike the use of an intermediate composite set at a telegraph repeater point. Therefore, if thump is experienced, a terminal composite set should be used or additional noise-killer placed in the simplexed circuit. If the simplexed circuit consists, for example, of more than 20 miles of simplexed phantom in cable, the signals reaching the intermediate composite set should be rounded off sufficiently to obviate difficulty from thump.

In telephone circuits having repeaters adjusted for large gains, the amount of telegraph thump which will be obtained must be given consideration. The telegraph thump current is usually amplified by the repeater in approximately the same ratio as the telephone currents, particularly if the repeater is designed for the direct amplification of 135-cycle ringing current, and the telegraph thump in succeeding sections, while not adding directly, will increase the total interference.

Telegraph thump caused by the metallic telegraph system is normally not appreciable for a single repeater section but in the case of a number of repeater sections operated in tandem may manifest itself by noise which is not readily identified as telegraph thump.

6.0 Telegraph Flutter.

Telegraph flutter, as distinct from telegraph thump, occurs only on loaded conductors and is effective only when voice currents or currents of voice frequency are transmitted over the circuits. It is due to the variation in transmission equivalent of the telephone circuits which accompanies in greater or less degree the fluctuations of telegraph current over the loaded conductors. The variations in the telegraph currents cause transient increases in the effective resistance of the loading coils to the telephone currents with resultant transient increases in the transmission equivalent of the circuit. The increase in effective resistance is accompanied by an increase in inductance but this change in inductance is usually not great enough to affect materially the transmission equivalent of the telephone circuits.

The magnitude of the change in the effective resistance of the loading coils depends upon the core material used in the coils, the amount and the frequency of the telephone current flowing through their windings, the inductance of the coils and the wave shape, frequency and magnitude of the telegraph current. The total flutter effect on the telephone circuit depends also, of course, upon the length of the circuit. Distortion may be produced by flutter in the telephone circuit since the flutter effect is different for different voice frequencies.

The amount of the change in the constants of the loading coils is largely dependent upon the rate of change of the telegraph current. The effect is present only during the instants of time in which the telegraph current is changing and not while it is flowing in unvarying amounts over the circuit. A steady current equal to the peak value of the normal telegraph current would produce no appreciable change in the loading coil constants.

Full duplex telegraph operation causes greater flutter than half duplex operation since the changes in the value of the telegraph current are more frequent. When conversation is carried on over a circuit affected by an excessive amount of flutter, the voice of the speaker at the distant end sounds as if it were husky or trembling. If a single frequency current of voice frequency is sent over the circuit, the tone in the telephone receiver at the receiving end sounds unsteady due to the momentary changes in its volume caused by the effect of the telegraph current. The flutter effect can be much more easily observed when a single-frequency tone is sent over the line than when conversation is carried on, and consequently a test for flutter should be made with a single frequency tone and with voice currents.

Flutter occurs normally on the composited side and phantom circuits only, since on simplexed circuits the telegraph current flows through the windings of the loading coils in parallel opposing.

The flutter effect is usually greatest when the telephone and telegraph transmissions are both in the same direction. Tests for flutter should therefore be made under different conditions of telephone and telegraph transmission to make certain that the maximum flutter has been observed.

6.1 Rating of Loading Coils from a Flutter Standpoint.

As already pointed out the flutter effect varies with the types of loading coils used. From a flutter standpoint, the types of loading coils which are in place in the plant may be classified as follows:

	Approximate Relative Flutter
Open wire and large gauge cable coils	
Low permeability wire core with air gap	1
Small size cable coils	
Permalloy coils	1.5
Low permeability wire core without air gap	2
Low permeability solid core	3
High permeability solid core	5
High permeability wire core	7

6.2 Requirements for Avoiding Excessive Flutter.

With the growth both in the length of loaded toll circuits and in the extent to which superposed telegraph operation is used in the telephone plant, it was found that with types of loading coils formerly standard excessive flutter would be caused under many conditions of operation. It was necessary, therefore, in order to provide for the possibility of extensive grounded telegraph operation without noticeable flutter in the telephone circuits to develop new types of loading coils both for open wire and for cable use. The types of coils which have been developed make possible a very extensive use of telegraph, using the standard types of telegraph apparatus. For toll cables, in general, it is necessary not only to use the best types of coils but to limit the telegraph current to a small amount. The metallic telegraph system was developed for superposing telegraph circuits on small gauge cable telephone circuits by compositing.

6.3 Conditions of Telegraph Operation.

Although the development of improved types of loading coils has made possible the general use of toll circuits for superposed telegraph operation without excessive flutter effects, it is still necessary to observe certain limitations in the telegraph operation in order to avoid excessive flutter effects. As the magnitude of the flutter effect in a circuit depends upon a large number of factors, it is evident that the general application of any single rules for limiting flutter can be made and used only with a good deal of caution, and the results obtained are checked in each important case by test. In general, the following data give a basis for estimating the order of magnitude of the effect when any of the grounded telegraph systems are used on cable circuits:

a. In the case of large gauge toll cable circuits up to about 225 miles in length, telephone transmission should be satisfactory from a flutter standpoint if the cables are loaded with coils of the highest grade (i.e., least flutter) as described above, and telegraph is operated on both wires of the side circuit half-duplex with the telegraph current limited to 55 milliamperes. This is the minimum current giving satisfactory operation with standard telegraph apparatus.

b. If the cable phantom circuits up to about 200 miles in length are composited instead of the side circuits, coils of the highest grade being used, satisfactory telephone transmission from a flutter standpoint will be obtained with full duplex telegraph transmission on both sides of the phantom if the telegraph current is limited to 55 milliamperes.

c. In the case of circuits loaded with types of coils other than those of the highest grade, the limiting lengths for satisfactory avoidance of flutter are, in general, reduced approximately in the ratio of relative flutter effect.

The average magnitude of the telegraph flutter effect is measured approximately by making a transmission measurement of the telephone circuit with the superposed telegraph circuits not operating and then with the circuits carrying normal traffic. The difference between the results obtained in the two measurements is the average increase in transmission equivalent due to flutter. In making measurements of this type, care is taken to interpose a high pass filter between the line circuit and the transmission measuring set which prevents telegraph impulses of the lower frequencies from reaching the measuring set. As noted above, these lower frequency currents are of considerable magnitude and they will materially affect the accuracy of the measurements if they are not prevented from reaching the transmission measuring set.

The metallic telegraph system is especially designed to use a low potential and small currents for operation over the line circuit. This system therefore does not in general cause appreciable flutter effect in the telephone circuit.

7.0 Coordination of Telephone and Carrier Telegraph Systems.

The voice frequency carrier telegraph system uses for transmission over the line circuit frequencies which are in the telephone range so that the problems which are involved in the use of this system are largely crosstalk problems. With the standard operating routines, interference due to level differences is normally not a factor in the operation of voice frequency carrier telegraph systems and telephone circuits on adjacent cable pairs. In the operation of the voice frequency carrier telegraph system over a considerable distance, it is undesirable because of flutter considerations to employ, simultaneously, metallic telegraph operation on the same conductors.

The operation of high frequency carrier telegraph systems may involve a consideration of level limitations in order to prevent interference when carrier telephone or voice range telephone circuits are operated simultaneously on adjacent conductors. It is normally not feasible to operate a voice frequency carrier telegraph system on carrier telephone channels.

8.0 Noise from Telegraph Power Plants.

The use of standard power plant arrangements in connection with telegraph operation does not normally result in noise in the telephone plant. In connection with the operation of telegraph stations, however, power for line operation may be obtained from local direct current lighting circuits or from motor generators associated with telephone typewriter apparatus. Noise from these sources may occasionally be produced either in the telephone circuit on which the telephone typewriter is superposed, or, if superposition is not employed, on the adjacent conductors. Noise difficulty of this type may be obviated by the use of suitable filter or retardation coil arrangements in the power supply leads.

TELEPHONE TYPEWRITER OPERATION

9.0 General

The telephone typewriter is a device operable by signals sent over telegraph circuits. The circuits may be long, employing several repeaters, or relatively short involving only a single wire connecting the sets.

The usual instrument consists of a keyboard similar to the typewriter keyboard and a printing mechanism designed to print the message on either tape or page. The keyboard may be omitted for " receiving only " service, or, in case the traffic volume is large, a sending device consisting of a perforator and an automatic transmitter may be employed.

Telephone typewriter service is given over the same types of telegraph systems as for manual service, the typewriter equipment being substituted in the subscriber loop circuits for the usual telegraph key and sounder.

There are two types of systems in general use, the " start-stop " and the " multiplex." The former is a single channel system and the latter a multichannel system. The multiplex provides two, three or four channels over a single telegraph facility and is of particular value where heavy traffic is involved as on trunk circuits. The start-stop system permits flexible layouts having a large number of sets. The telegraph companies use both systems but the Bell System uses only the start-stop.

10.0 Principles of Operation.

The simplest method to use in operating two typewriters together is one employing a wire to connect each key lever on the sending machine to its corresponding typebar on the receiving machine through a mechanism which handles the printing of the proper character when a key lever is depressed. This method is not economical except in cases where the connecting circuit is of the shortest possible length, and is therefore not used, since it is desirable to have standard arrangements which can be applied to circuits of all lengths in common use.

Another method of operation is obtained by use of a signal code, where a given signal causes the printing of a certain character. There are many different codes that might be used, but when the conditions that the code must satisfy are determined, there is perhaps only one or two codes that will satisfy them without the provision of elaborate mechanisms for handling the signals. The Bell System apparatus is so designed that the code employed must satisfy the following conditions:

1. The code must employ only two current values, such as "current" and "no cur-

rent," in order that the machines may operate over long line telegraph systems which are designed to transmit only two line conditions.

2. The number of code elements per character must be a minimum in order to permit high-speed operation over relatively low-frequency telegraph circuits.
3. The number of code elements per letter must necessarily be uniform in order to give a simple machine design.

The "five unit" code fulfills these requirements and is used on the telephone typewriter. Figure 10 shows a diagram of the code. Examination of

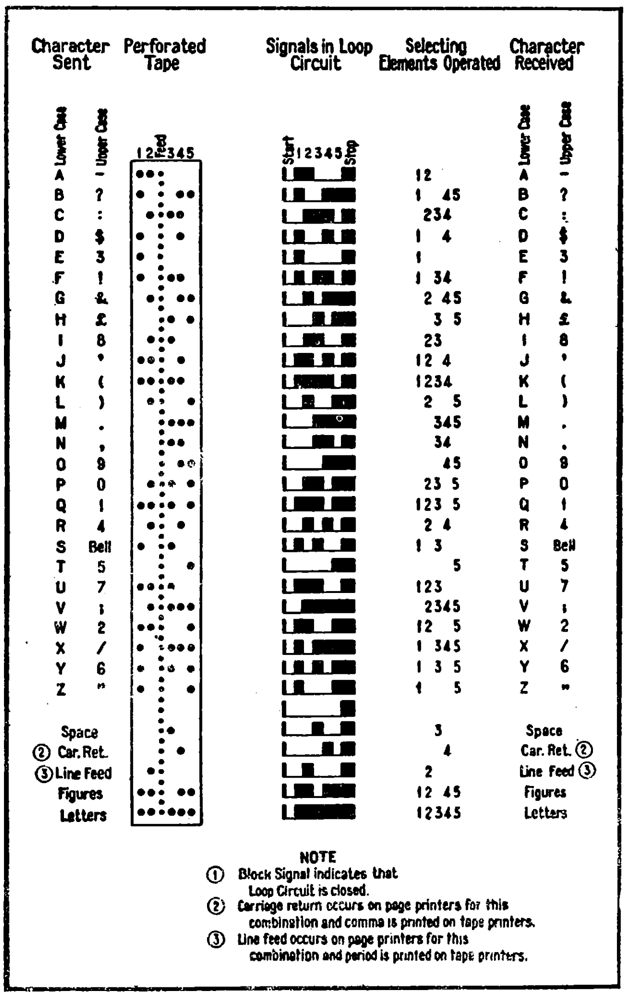

Fig. 10.—Printing Telegraph Code of the Start-Stop System.

the code shows that a total of 32 signal combinations are possible. It will be noticed that these combinations furnish 26 letter selections, 10 figure selections, 5 "stunt" or operation selections, and all the necessary punctuation selections. The upper case functions are performed by the depression of the various letter keys after the figures shift selection has been transmitted. The machine is returned for lower case operation after the "letters" signal has been transmitted.

The "six unit" code is used on some stock tickers. This code provides for the transmission of 64 signal combinations, thereby eliminating the necessity for employing the "figures-shift" mechanism.

After having selected a code some means must be devised for sending and receiving the signal impulses. One method of doing this is to make use of a five-wire system, in which each wire carries a particular signal impulse. This system, as is obvious, is uneconomical with regard to line facilities, and is not used. By making use of a synchronizing arrangement, it is possible to operate telephone typewriters over normal telegraph facilities. Synchronism provides a means for keeping two or more machines in step. That is, the sending and receiving machines are kept in phase throughout the operation of sending signal combinations so that as the sending machine is transmitting a No. 1 impulse the receiving machine is in a position ready to receive it, and so on for each successive signal impulse.

10.1 Multiplex

The multiplex system uses the five-unit code, and "continuous" synchronism, that is, the machines are kept in phase by correcting their speeds by the use of the selecting code impulses; extra pulses not being required.

Figure 11 shows schematically the multiplex sys-

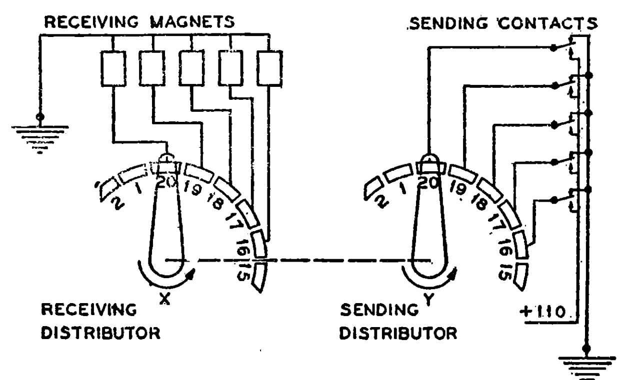

Fig. 11.—Simplified Circuit of the Multiplex System.

tem. Channel four is shown with a part of one and three. At Y is the sending distributor arranged for transmitting five-unit code impulses. At X is the receiving distributor arranged to receive five-unit code impulses. The distributors are operated by phonic wheel motors, the speeds of which are controlled by tuning forks. The brush arms are geared to the motor shaft and revolve at a speed about one-fifth that of the motor. One distributor's speed is controlled by the other; the controlled distributor operating at a slightly greater speed, having an angular velocity of ¾ to 1 degree per revolution greater than that of the controlling distributor.

There are two synchronizing methods for keeping the machines in step. One maintains synchronism by a retarding action ("mechanical" method) applied to the brush arm. The other maintains synchronism by electrically reducing ("electrical" method) the tuning fork speed which in turn retards the motor speed. The mechanical arrangement is more commonly used.

The line frequency in dots-per-second with the multiplex system is computed as follows:

$$\text{Dot-Frequency per second} = \frac{\text{Operations per minute}}{60} \times \frac{5}{2} \times \text{No. of channels}$$

where

$$\frac{\text{Operations per minute}}{60} = \text{Brush Arm revolutions per second}$$

and

$$\frac{5}{2} = \frac{\text{5 unit impulse}}{2} = 2.5 \text{ dots per brush arm revolution per channel}$$

Example:

$$\text{B.A.R.P.M.} = 360$$

whence

$$\frac{360}{60} \times \frac{5}{2} \times 4 = 60 \text{ dots per second (for a 4 channel system)}$$

An easy rule to remember in this connection is that the dot frequency over the line for a four-channel system is equal to the nominal word speed per minute. For example, 360 operations per minute is called 60 words per minute service—thus 60 dots per second, line frequency. For a three-channel system, the line frequency is ¾ the channel speed in words per minute.

10.2 Start-Stop.

Figure 12 shows the elements of start-stop synchronism consisting of a sending and a receiving selecting arrangement, and an arrangement for transmitting start and stop impulses. A distributor with connections to a set of six transmitter contacts comprises the sending selecting arrangement. A distributor with connections to a set of seven contacts, five of which are connected to selecting magnets, comprises the receiving selecting arrangements. A tape lever or keyboard contact together with a permanent connection between the transmitter contact bus bar and a sixth impulse segment on the distributor comprises the start magnet circuit which is controlled by the sending end arrangement. The operation is as follows:

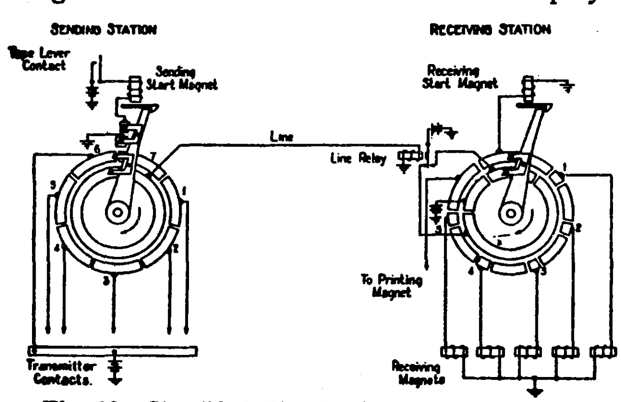

Fig. 12.—Simplified Circuit of Start-Stop System.

Assume it is desired to transmit the letter "E" signal combination. No. 1 segment of the sending distributor will be connected to the transmitter bus bar simultaneously with the closing of the keyboard contact key, no other signal units being selected. Closing the keyboard contact closes the start magnet circuit energizing the start magnet thus releasing the sending brush arm and starting the transmission of signal combination for the letter "E." As the brush arm passes to segment seven, a spacing impulse is sent to the receiving circuit releasing the receiving line relay. Release of this relay causes the actuation of the receiving start magnet thus releasing the receiving brush arm. As both distributors operate at the same speed, the receiving brush arm will be just moving on segment No. 1, as the sending brush arm is reaching the middle portion of segment No. 1 of the sending distributor. The receiving segments are much shorter than the sending segments. When both brush arms are on No. 1 segment a marking impulse is sent over the line, and the receiving line relay armature moves to its marking contact, connecting battery through the receiving brush arm contacts to No. 1 selecting magnet. Through the remainder of the operation the signal impulses are spaces, causing the receiving line relay armature to move to the spacing contact thereby leaving selecting magnets 2, 3, 4, and 5 in their unselected position. As the sending brush arm moves on to the sixth impulse segment, a marking signal is sent out on the line operating the line relay to its mark position, thereby holding the receiving start magnet armature in its open position ready for the next start impulse. After the sending start magnet is operated, releasing the sending brush arm at the beginning of the operation, the keyboard contact is opened, so that when the sending brush arm completes its revolution it will be held until the next selection is made.

It will be seen that the receiving mechanism must wait for its start impulse to come from the sending mechanism, and that, to be put back to normal after a signal selection has been made, a sixth or stop impulse is transmitted over the circuit. In the diagram of the transmitted signal impulses for the various characters in Figure 10, a signal combination is shown to consist of start—five selecting—and a stop impulse,—adding as follows: $1+5+1.5=7.5$ impulses. The line frequency is therefore 50% higher than it would be if only 5 impulses were transmitted. The method for computing line frequencies is the same as for the multiplex. Since the start-stop system employs only one channel per circuit, the number of channels is one, and the "dot frequency per revolution" is $\frac{7.5}{2}$, so that

$$\text{Dot frequency} = \frac{\text{Operations per minute}}{60} \times \frac{7.5}{2}$$

This system compensates for lag of the sending equipment by placing the control of the stop impulse in the sending equipment. Lag of the receiving equipment is also taken into account by the sending equipment. It is necessary for the sending mechanism to come to a stop at the end of each operation. This compensates for any small amount of lag in the receiving device.

Although the system requires extra pulses to maintain synchronism, it is nevertheless well adapted for use in the Bell System for the following reasons:

1. Automatic compensation for lag gives flexibility for intercommunication between a large number of stations.
2. It is possible to employ simple motors, easy for patrons to start and stop, and adapted for operation on power supply available in their offices.
3. Simple telephone typewriter machines are employed.

11.0 Application of Principles.

11.1 General.

The employment of the principles discussed above in the telephone typewriter permits some freedom in the design of the design of the necessary equipment. Several types of typewriter sets are now in use and all are similar in regard to the units which they comprise. The differences are to be found in the mechanisms employed to provide the necessary operations. In the newer sets most of the operations are mechanical; features being added which permit the use of lighter mechanisms requiring less operating power.

The apparatus consists in general of a keyboard distributor and printing unit. The keyboard distributor performs two functions; the sending out of signal impulses, and the receiving and sorting of incoming signal impulses. The printer handles the selections after they have been received.

"Automatic transmission" is the sending of signals from a perforated tape, and requires a more elaborate arrangement of equipment, consisting of a keyboard-perforator, an automatic transmitter, a distributor and relay box. This arrangement prepares a perforated tape which is fed through an automatic transmitter, transmits the signal impulses into the line, and receives and sorts incoming impulses from the line.

11.2 Operation of Sending Equipment.

The sending equipment is of the commutator type or the cam type. The commutator, or segmented ring distributor, is the older and is not so simple in its operation as the cam distributor. A description of the operation of the commutator distributor was given in the discussion of start-stop synchronism. The cam distributor, while it performs the same operations, does so in a different manner. This distributor is actuated through a clutch mechanism which engages each time a key-lever is depressed. A set of six contact levers rests against a cam drum and comprises the main part of the distributor mechanism. The cam drum has a series of indents on its surface into which the various contact levers fall when they are in their selected position. The action permits the closing of a set of transmitting contacts with the selection of each contact lever. This arrangement performs the same operations as are performed with the movement of a brush over six sending segments.

11.3 Operation of Receiving Equipment.

There are several types of receiving mechanisms; one employs a commutator distributor similar to that used in the sending equipment. Another employs a cam distributor, and a third employs a semi-mechanical distributor.

The cam type receiving distributor consists of a cam drum arranged with indents similar to the sending distributor. Against the surface of the drum rests a set of seven contact levers which control the closing of a like number of receiving contacts. The seventh contact controls the operation of a receiving start magnet. The other six contacts perform the same functions as the six segments on the receiving commutator distributor.

The semi-mechanical distributor mechanism consists of a selecting magnet and a sword and cam arrangement. The magnet operates on a "current-no current" basis; that is, a selecting impulse causes the magnet to operate, and an unselected impulse causes it to release. To the armature is connected an extension arm which, in moving back and forth from the selected to unselected position, operates a sword arrangement with the aid of a cam mechanism and causes selections to be set up on a series of five code bars. This mechanism is used on machines which print the received messages on a tape; the other mechanisms are used on page printers. Tape printers are the simpler in operation. All of the receiving devices provide for an over-lap feature, that is an arrangement whereby the selecting mechanism is in the process of setting up a new selection while the printer unit is printing a previously selected character. This permits the moving parts to operate at a lower speed than would be possible if the feature were not employed.

After the received signals are set up on the code bars in the printer unit, characters are printed or stunts performed by the action of an arrangement of cams.

11.4 Speed.

The speed of operation of the several sets is designated in "operations per minute" and "words per minute." Words per minute are determined by assuming all words to consist of five letters and a space, and dividing the number of operations per minute by five plus one; i.e. if a machine is operating at 360 operations per minute, the speed in words per minute is 60 and is called 60-speed. Two speeds are in common use, "60-speed" and "40-speed." At the present time, the trend is toward 60-speed operation.

In the older type sets the operating speeds of the sending and receiving distributors were the same. In the newer type the receiving cam revolves at approximately 14 per cent. greater speed than the sending cam. The angular displacement between indents on the receiving cam drum is also 14 per cent. greater than between those on the sending cam. This arrangement cuts down the stop time of the receiving distributor, permitting greater operating speed for a given line frequency, but also makes more difficult the selection of speeds at which this type of set will operate satisfactorily with the commutator type sets.

At high speed, sending and receiving distributors of the commutator type set operate at 360 operations per minute, while the sending and receiving distributors of the cam type set operate at 368 and 420.6 operations per minute respectively. Since the sending distributor controls the set operation its speed fixes the operating speed of the set.

Although the operating mechanisms of the various typewriter sets are different they may be operated together. If one set operates at 360 operations per minute and another at 368, the speeds of the sets are adjusted so that their line frequencies match. The speeds of the sets may be adjusted by various methods. The one most commonly used in the Bell System employs a spot target, mounted on the end of the distributor motor shaft; the target being viewed through a specially arranged tuning fork. The tuning fork has two slotted metal pieces attached to its prongs so that the slots normally over-lap. When the fork is set to vibrating the slots are uncovered for each vibration so that it is possible to look through the slots at the spot target. The speed of the distributor motor is adjusted by a governor arrangement so that the spots on the target will look to be standing still when observed through the openings of the tuning fork. Changes in speed may be made by using targets having different numbers of spots.

The method by which it is possible to determine the number of spots which a target must have to allow adjustment to a given speed is as follows:

The number of spots which can readily be observed on a target of the dimensions used must fall somewhere between 7 and 23. In a particular type of receiving distributor the receiving cams are spaced 55.5 degrees apart, assuming that it is desired to design a target for this machine which will adjust the speed of the receiving distributor to operate with signals being received at the rate of 22.75 cycles per second. From these data the speed of the receiving distributors may be computed as follows:

$$\frac{22.75 \times 2 \times 60 \times 55.5}{360} = 420.6 \text{ revolutions per minute.}$$

The gear ratio between the motor and receiving distributor set is 5 to 1. The motor speed therefore must be $5 \times 420.6 = 2100$ revolutions per minute.

If the tuning fork vibration speed is 87.62 cycles per second, the number of times the slot on the tuning fork will be visible per revolution of the motor shaft is $\frac{87.62 \times 60}{2100} = 2.5$. It is, of course, necessary to have a whole number of spots on the target and the whole number multiples of 2.5 which fall within the visible limits of 7 to 23, which was mentioned above, are 10, 15 and 20. A target with either 10, 15 or 20 spots would be satisfactory for adjusting the speed of this distributor.

12.0 Operating Margins.

In considering the margins of operation of the telephone typewriter, it should be kept in mind that almost the entire functioning of the machine is marginal, that is to say, for satisfactory operation the various adjustments must be kept within certain limits. This is true not only as regards most of the mechanical adjustments where it is important that they be maintained within the specified limits around which the apparatus has been designed, but it is especially true with regard to those adjustments which are directly related to the transmission or reception of the telegraph signals.

Some of the most important adjustments of the telephone typewriter are those having to do with margins for satisfactorily receiving the signals over the line circuit. Variables which affect these margins are the following:

1. Distortions in the original signals from the sending distributors. (Ordinarily held within ± 5 per cent.)
2. Distortion in the signals during transmission over the line.
3. Speed variations between sending and receiving distributors.
4. Accuracy of adjustment of the receiving distributor mechanism, especially the orientation adjustment.
5. Characteristic of the receiving distributor design as regards these operating margins.

Bias usually comprises part of the distortion experienced in received signals. Bias may be either "marking" or "spacing," the first causing a lengthening of marking signals and a shortening of spacing signals, the second causing a lengthening of spacing signals and a shortening of marking signals.

Sending distributor distortion is largely due to delay in brush arm release and slippage, and is usually small. Distortion of signals in transmission is due to a number of factors, the most important being improper adjustment of repeater relays and unstable line facilities. Speed variations contribute some bias and the effect is a lengthening or shortening of the start impulse. If the speed variation is considerable, character impulses will be gained or lost. Orientation, if improperly adjusted, will cause errors to be printed, the receiving distributor picking up or losing impulses.

A receiving distributor designed to operate at 60-speed, as in the case of the cam type distributor, may be difficult to adjust so as to secure a satisfactory operating margin at 40-speed. To provide as much margin as possible, the receiving segments of the commutator distributor are cut to approximately one half the length of the sending distributor. This, and the orientation feature, permit the receiving distributor to pick up the middle portion of the incoming signals, allowing the signals to have considerable distortion before errors are printed.

The orientation feature is an arrangement for rotating the receiving face a certain distance to left or right, making it possible to adjust its position so that maximum margin is secured on badly distorted signals. To determine a point in the orientation range where the operating margin is the same for both "marking" and "spacing" bias, a chart is made. The chart contains curves of orientation range versus percentage of marking and spacing bias, and a point is chosen where spacing and marking bias are the same. All sets should be capable of handling in the neighborhood of ± 42 per cent. bias. Orientation range is measured by moving the receiving distributor face or cam to right and left until errors occur in each case. The difference of the two settings is a measure of the orientation range.

13.0 Regenerative Repeater.

Where circuits are made up of a number of repeater sections it is found that the distortion encountered in the several sections is accumulative, and a point is reached, depending upon the amount of distortion experienced in the individual sections, where received signals are so poor that service is impaired. Even with the best facilities available there is a limit to the distance over which satisfactory service can be given. In the telephone typewriter service where machines are employed to send out signals, all impulses of which are equal in length, it is important that the impulses be as near to normal length and wave shape as possible when they arrive at the receiving end. To meet this requirement without limiting the distance for which typewriter service will be furnished, use is made of a "regenerative repeater."

The regenerative repeater eliminates distortion from the signals by momentarily storing the individual signal units and then retransmitting them by means of a motor-driven distributor similar to that used in the set at the sending end of the line. The signals leave the repeater practically free from distortion as though they were transmitted by a set at the repeater point. In effect, the regenerative repeater divides a long circuit into shorter circuits with the result that the distortion in the signal at the distant end is similar to that experienced over a short circuit. With the use of regenerative repeaters at appropriate intervals, it is theoretically practicable to operate satisfactorily a telegraph circuit of any length. The regenerative repeater functions satisfactorily at any repeater point where the distortion in the received signal is not greater than is permissible for satisfactory telephone typewriter operation at that point.

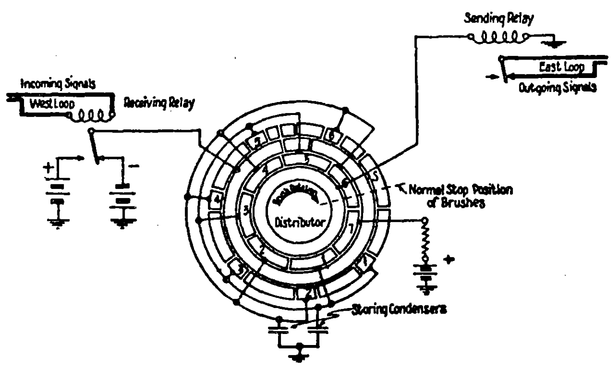

Fig. 13.—Simplified Circuit of Start-Stop Regenerative Repeater.

In regenerating the signals, the receiving relay (Figure 13) is connected to storing condensers through the brushes and the segments of the receiving face of a start-stop distributor during the short interval of time when the middle portion of each signal element should be controlling the receiving relay. After the signal is received, either a positive or a negative charge depending upon whether a marking or a spacing signal was received, is connected to a sending relay through the sending face of the start-stop distributor. The segments of the sending distributor are spaced in the same way as those of the regular distributor. Consequently the charges from the condenser operate the relay at accurately spaced intervals and signals are transmitted to the line which are identical with those originally transmitted from the sending station.

14.0 Suitability of the Various Telegraph Systems for Telephone Typewriter Service.

A very important part of a telephone typewriter service is the transmission system that carries the typewriter signals from one machine to another. The telegraph circuit has been mentioned with regard to signal distortion but not with regard to its specific suitability for typewriter service. There are a number of telegraph systems that are employed for telephone typewriter service. The suitability of these systems for telephone typewriter service is discussed in the next section.

LAYOUT OF TELEGRAPH CIRCUITS

15.0 General.

In the work of telegraph circuit layout, there are two distinct fields. The first of these involves the planning ahead of the necessary facilities and the provision of the circuits and equipment required for future service. The second concerns the utilization of existing facilities in setting up contracts. The planning and provision usually must be done a considerable period in advance of the time when the circuits and equipment will actually be put into service. For instance, providing plant to meet an estimate of 50 additional circuits between Pittsburgh and Chicago involves consideration of the route available, possible use of new routes, flexibility of the added facilities in connection with service to other towns, protection of the new facilities by existing or new facilities to other towns and similar inter-related matters. Meeting the estimated requirements for 50 new circuits, therefore, does not necessarily involve the addition of 50 new circuits on any one route even if only one type of telegraph system were to be employed between the two points. Possible choice between different systems of operation must also be considered.

For telegraph circuits of any considerable length in cable the voice frequency telegraph system is to be preferred to the metallic telegraph system and the grounded telegraph systems should, except for the shorter distances, be considered only for temporary or emergency use. On this basis the backbone circuits of the future telegraph plant in the cable areas will be provided entirely by the voice frequency telegraph system. These circuits will provide high grade telegraph transmission between the terminal points involved. The metallic and the grounded telegraph systems will be used for extending telegraph service from these terminal points to customers' offices where these are not located at terminal points on the voice frequency telegraph systems.

The matter of "back-hauling" is of considerable importance in providing a complete solution of the telegraph operating problem as regards an entire area. The points which should be kept in mind may perhaps be more clearly brought out by the discussion of a specific case. Consider, for example, the provision of telegraph service in connection with a toll cable which is planned for installation between two important cities. The cable is 240 miles in length and contains five intermediate telephone repeater points, of which only one is located at a business center of any importance. At first sight, an obvious solution of the telegraph problem is to operate by the metallic telegraph system with metallic telegraph repeaters at every other telephone repeater point. This involves a choice at each telegraph repeater point between the use of terminal or through intermediate metallic repeaters, the through repeaters being used in connection with circuits passing through the repeater point without a drop. All of the metallic telegraph repeater sections will contain intermediate composite sets at one point with resultant reaction upon the quality of metallic telegraph operation. Through operation would therefore not be entirely satisfactory for circuits operated at 60 speed and which form part of large layouts.

Consideration of the problem involved in this case indicates that through service without intermediate drops may be taken care of by the provision of facilities by the voice frequency carrier telegraph system. Telegraph service to intermediate towns can be provided by using the metallic telegraph system with terminal or through repeaters at the various telegraph repeater points as required to meet service conditions. Neither of the two towns which would logically be chosen for telegraph repeater stations is an important center and consideration must be given to the extension of service from these repeater stations to the towns at which drops are located.

16.0 Power Supply for Local Telephone Typewriter Circuits.

In the present state of development of telephone typewriter service it is not necessary to make special provision for power supply for circuits which are wholly within an exchange area. These circuits will in general be operated without repeaters. In many cases a station at one end of the circuit will be located in an area having direct current power supply on a three-wire basis. In such cases the lighting circuit in the office can be used for supplying power for the line circuit and for the control circuit if one is provided. In many other cases a motor generator set is provided at the station as an adjunct in connection with normal operation of the telephone typewriter equipment, and it is usually possible to employ the motor generator set as a source of power for the line circuit. Where this is done care should be taken to insure that the motor generator set is not overloaded since this may result in a material reduction in operating margin of the line circuit. In still other cases it may be possible to use the normal telegraph batteries or 48-volt central office battery as a source of power for line or control circuit.

17.0 Circuits Within an Exchange Area.

For circuits up to about 15 miles in length it is neither economical or necessary, in general, to obtain telegraph facilities by super-position although there may be cases where an existing telephone tie line between private branch exchanges may be simplexed to provide a telegraph channel. This practice sometimes leads to complication and each case of the kind requires individual consideration because of the reactions to the general operation of the private branch exchange. For instance, if the P.B.X. is provided with several tie lines which have been working on a common battery signaling basis, it will be necessary to change all of them to ringdown operation if only one tie line is simplexed for telephone typewriter service.

Circuits connecting stations within an exchange area are generally provided by assigning pairs specifically for telegraph operation. The plant involved frequently is all-cable so that the bringing of all circuits to a central point for testing and patching in case of trouble is not warranted. In the case of circuits connecting distant points it is obviously desirable to provide testing and patching facilities because of the greater length of the circuits involved and the repeater equipment connected to them.

To assure satisfactory service where the local cable plant is involved, it is necessary for the departments concerned to have an appreciation of the factors involved in telegraph service so that care will be exercised in cable splicing and the running of cross-connections to avoid interference to service. The tagging of circuits at cross-connecting points is of material assistance in this respect. It may be found necessary also to mark cables containing telegraph circuits and to adopt special procedures which will reduce to a minimum the crossing, grounding or opening of pairs carrying telegraph circuits. It is necessary for the plant forces to be familiar with the operating requirements involved in telegraph service so that prompt action can be taken in locating and clearing trouble on a circuit when it arises.

The problem of giving satisfactory service within an exchange area is considerably simplified by proper layout of the circuits. If a number of stations scattered about the area are involved, more satisfactory service can be given if each of these stations is connected to the main station by an individual line rather than having the stations connected together by a single circuit. Where a single circuit only is employed, trouble anywhere on the circuit will put the whole system out of service until the trouble is located. Where the stations are located on individual lines, however, trouble on one line will not seriously react upon the remainder of the system. The provision of separate circuits to each of the outlying points together with switching arrangements at the central point is generally more satisfactory to the subscriber from an operating standpoint.

18.0 Circuits Connecting Distant Points.

The second field involved in telegraph layout work is the utilization of the facilities already provided in setting up circuits for new contracts. The forces engaged in this work usually are thoroughly familiar with the operating characteristics and limitations of the various telegraph systems which can be used in the available plant. Considerable responsibility rests upon the man in charge of the detailed layout work since the amount of characteristic distortion to signals passing over a circuit depends almost entirely upon the layout used. Careful consideration is necessary in the case of complicated circuits especially where two-way service is required between all of the stations on a circuit. In some cases the operating requirements may be materially simplified by a change in the service which the layout is to give. For instance, in a case where it is very difficult to give two-way service between all the points involved on the network, it may be relatively easy to give satisfactory two-way service between any point in the network and a central point.

Considering for a moment extremes only, it is possible for a circuit to be set up in either of two ways:

1. With long repeater sections working to the limit requiring a large amount of skilled repeater attendance.
2. With short repeater sections and a very stable layout so that the work of keeping the circuit going becomes mainly a matter of good relay maintenance and maintenance of the line conductors.

In the case of the telegraph circuits of the Long Lines Department and in some of the Associated Companies it is necessary to lay out certain circuits which fall in the first class. In less exacting cases, however, it is possible to lay out the circuit so that satisfactory service can be given with a minimum of repeater attendance. It is possible, for instance, to operate a circuit by the metallic telegraph system with one or two repeater sections which will provide operation so stable that the only repeater attendance necessary is to replace the relays on a routine basis by newly adjusted relays.

A trial is being made of a layout plan in which a figure of de-merit is assigned to a repeater section operated by the different standard telegraph systems. The quality of operation which can be obtained over the entire circuit is considered satisfactory if the sum of the figures of de-merit for different repeater sections is below a certain limit. This method is merely in the trial stage at the present time, and it is not yet possible to consider its general application throughout the field. It gives only approximate results, of course, and must be checked by other methods of estimating quality of operation.

19.0 Open Wire Layout Considerations.

19.1 Circuits.

The use of open wire circuits solely for telegraph purposes is practically never economical, so that where open wire is involved it is necessary to consider the provision of service by superposition on working telephone circuits, either by simplexing or compositing the telephone circuits or by employing the high frequency carrier telegraph system. To provide circuits of an especially high grade, it is frequently the practice to install a high frequency carrier telegraph system in advance of the complete use of all of the compositing possibilities.

For the longer hauls compositing is used rather than simplexing because of the lesser leakage effect with composited circuits. Because of leakage a composited side circuit is normally to be preferred to a composited phantom circuit on open wire. For the shorter hauls, simplexing of side circuits or even of phantom circuits permits giving service economically by means of the neutral system in cases where it is desired to connect a number of stations in series which are relatively close together. In general, however, the use of simplexed facilities in open wire should be considered as a stop-gap arrangement.

For operation over composited circuits it usually is desirable to use polar transmission or, in the case of operation to outlying points, the upset half duplex method of operation. For composited circuits in open wire the neutral system of operation will usually be satisfactory only at 40 speed and for relatively short distances so that this method of operation should be considered as a stop-gap arrangement. With lines in good condition and without intermediate composite equipment upset operation can usually be relied upon to give satisfactory service at 60 speed for section distances of 50 to 100 miles. For 40 speed operation the distance may be increased to about 150 miles. The use of a composited phantom circuit cuts these distances approximately in half and the presence of intermediate composite equipment also reduces the permissible operating distances.

19.2 Repeaters.

Where reliable operation is required over open wire circuit for the longer distances it is necessary to provide appropriate intermediate repeater equipment. The telegraph systems from which a choice can be made are normally the bridged polar duplex telegraph system, the differential duplex system, the one-way polar system and the high frequency carrier telegraph system. Of these the one-way polar telegraph system is available only for one-way service. The use of the bridge polar duplex telegraph system is normally limited to circuits involving operation on a manual basis or telephone typewriter service at 40 speed. Because the manufacture of this type of equipment has been discontinued the use of bridge polar duplex repeaters is limited to points where they happen to be available. The differential duplex telegraph repeaters are considerably more satisfactory at 60 speed.

Where repeater sections can be obtained with type B intermediate composite sets or without intermediate composite sets, the maximum length of repeater section with polar duplex equipment is about 350 to 400 miles for facilities in 104 copper. This, however, should be considered a limiting figure and with the present necessity for at least one intermediate composite point in a telegraph repeater section the telegraph repeater spacing for 104 copper is about 200 to 250 miles. With repeater sections of this length containing not more than one intermediate composite set point and with differential duplex telegraph repeaters, operation at 60 speed should be satisfactory for two repeater sections. If 60 speed operation is desired by the polar duplex method in open wire for more than two repeater sections a regenerative repeater is employed.

The one-way polar telegraph system is especially stable and reliable and will give satisfactory operation over facilities which because of make-up and condition would be unsatisfactory for operation with any other standard d-c. telegraph system. This system is simple and flexible and is of considerable service in reaching outlying points where one-way telephone typewriter service is involved. Since a balanced arrangement is not employed the system can be operated with a minimum of repeater attendance.

The high frequency carrier telegraph system is operated with channel terminals at the points where connection to other telegraph systems or drops is required. At intermediate repeater points all of the channels of a system are repeated in one common vacuum tube repeater. The lengths of carrier repeater sections are usually determined by other than telegraph transmission considerations. Service given with the high frequency carrier telegraph system is satisfactory for operation at 60 speed.

It should be remembered that the open wire telegraph systems are more subject to fortuitous distortion than the cable telegraph systems. This factor may considerably affect the length of repeater sections or the operation which can be obtained with any given system. The grounded telegraph systems are subject to cross-fire, inductive interference and ground potential while the high frequency carrier telegraph system is subject to interruption by static.

20.0 Cable Layout Considerations.

As mentioned previously, for circuits up to about 15 miles in length it does not appear economical in general to obtain telegraph facilities by superposition although there may be cases where superposition may be justified. It will also be necessary usually to provide circuits specifically for telegraph operation between points having toll service on an A-B toll basis since this method of toll operation uses all of the available grounded channels for telephone signaling. For distances greater than 15 miles or for operation between points having ringdown toll service, superposition by compositing or simplexing is usually practicable. The use of spare pairs for distances greater than about 15 miles is, in general, uneconomical.

Where spare pairs are available which can be assigned wholly for telegraph operation, satisfactory service at either 40 or 60 speed can be given with the neutral telegraph system using single conductors up to distances beyond which the normal line current can not be obtained even by using 130 volt batteries at both ends of the circuit. (This consideration of grounded operation in cable is based on the use of a protective resistance of 350 ohms between each 130 volt battery and the line circuit.) Where simplexed pairs or simplexed phantom circuits are available, best operation is obtained by using a line battery of less than 130 volts at each end of the circuit. It is usually convenient to approximate this method of operation by using 130 volt batteries with a potentiometer arrangement between the battery and the line circuit which reduces the potential applied to the line. Circuits of this type when operated with low terminal impedance give satisfactory operation on a neutral basis without repeaters for considerable distances, as indicated in the accompanying table of practical limits:

PERMISSIBLE OPERATING DISTANCES FOR TELEPHONE TYPEWRITER SERVICE.

(Neutral Operation in Cable.)

	60 Speed	40 Speed
Simplexed Pair		
#14 (without line relay)..	35 miles	50 miles
#12 or #14 (with line relay)	55	55
Simplexed Phantom		
#14 (without line relay)..	35	55
#12 or #14 (with line relay)	55	60
Composited Side		
#14 (without line relay)..	Not Satisfactory	Not Satisfactory
#12 or #14 (with line relay)	30	35-40
Composited Phantom		
#14 (without line relay)..	Not Satisfactory	25
#12 or #14 (with line relay)	35-40	50

If it is desired to operate a section on the neutral basis as part of a long or complicated circuit, the permissible operating length of simplexed pair or simplexed phantom is materially reduced.

Polar duplex telegraph repeaters may be used in connection with cable facilities but this method of operation should be employed only as a stop-gap rather than as a permanent method of operation. Where circuits of the larger gauges (No. 16 gauge or larger) are available, composite operation may be employed with repeater sections as long as 100 to 115 miles provided the cross-fire between circuits in the same quad is neutralized and flutter effects are not experienced of a magnitude such that they interfere with telephone service. The use of simplexed phantomed circuits of No. 16 or No. 19 gauge will usually be found satisfactory. Circuits of this type do not occasion flutter in the telephone circuit and are not subject to much cross-fire.

The one-way polar telegraph system may be employed in connection with cable facilities for distances up to 100 or 115 miles. No arrangements have been developed to neutralize cross-fire between this system and other systems, so that for distances of more than 30 or 40 miles simplexed phantomed circuits are used.

The metallic and voice frequency carrier telegraph systems are employed at regular operation for distances greater than 100 miles. The voice frequency carrier telegraph system gives satisfactory operation at higher speeds than the metallic telegraph system, the latter not being suitable for speeds materially in excess of 60 speed.

21.0 Stop-Gap Arrangements.

The use of simplexed pairs in open wire facilities is usually precluded since the toll telephone circuits are generally phantomed. In areas where all of the circuits are phantomed the only possibility of operation on a simplexed basis is by simplexing the phantom circuit. Since the simplexed phantom circuit will have four times the leakage of a single wire under given weather conditions, the length of circuit over which satisfactory service can be given is materially reduced. On the other hand, where closely adjacent stations are to be connected together in series, compositing is undesirable from the cost and transmission standpoints. In such cases if the total length of circuit does not exceed the permissible length, the neutral system can be used for operation provided low terminal impedances are employed. Satisfactory service has been given over simplexed phantom circuits in open wire using the neutral telegraph system for distances up to 40 or 50 miles. In these cases the line has been in good condition and free from trees. With such facilities the use of low terminal impedances is absolutely necessary and operation by this method is not practicable between points having noticeable ground potential or power interference.

The transmission over a simplexed phantom circuit in dry weather is very good even with the neutral telegraph system. Operation in wet weather is greatly limited by the leakage effect, although there is sufficient operating margin in a section of simplexed phantom open wire not exceeding 40 miles in length to permit operation to a similar section through a single line repeater. Simplexed phantom circuits of considerably greater length than 40 or 50 miles operate very well in dry weather but under wet weather conditions considerable difficulty may be experienced.

In order to provide satisfactory service at 60 speed between points connected by facilities which are not of the highest grade and where carrier operation is not available, the double one-way polar method of operation has sometimes been employed. Since it possesses all of the good features of one-way polar telegraph operation, it can usually be relied upon to give satisfactory service over poor layouts. Its disadvantage is that two channels are required, one for operation in either direction.

21.1 Problems Involved During Periods of Cable Extension.

During the extension of a toll cable there is a transition period in which the telegraph layout becomes somewhat complicated and care must be taken to insure satisfactory operation. In many cases the cable will be rapidly extended to a point about 30 or 40 miles from one terminal of the future cable link and then the extension of the cable is halted for a time. A situation of this sort presents more difficulty than the case where the cable is pushed rapidly to a point about 100 miles from the cable terminal. In the latter case metallic telegraph operation may be employed over the newly constructed cable but where the cable extends only for 30 or 40 miles metallic operation will not prove in. The use of simplexed phantoms in the cable part of the circuit connected through intermediate composite sets to the open wire part of the telegraph repeater section will usually be satisfactory if the open wire is not more than 100 to 150 miles in length. This method of operation should not produce noticeable thump in the telephone circuits provided the simplexed phantom part of the circuit is 30 miles or more in length. If the part of the circuit in cable is shorter than 30 miles it may be necessary to employ a terminal composite set at the junction with the open wire.

During the period when a toll cable is being extended consideration must be given to the operation of high frequency carrier telegraph circuits. It is generally undesirable to dismantle entirely the open wire line which the cable parallels. Terminating the high frequency carrier telegraph system circuits at the end of the cable requires the provision of repeater apparatus for extending through to the cable terminal. Retention of conductors on the open wire line sufficient to bring the carrier telegraph system through to the end of the open wire line will usually be found practicable and economical.

A method of stop-gap operation is the use of bridge polar duplex repeaters for operation at 60 speed. The use of a No. 215-A relay in place of the No. 31-A relay normally used as a receiving relay, and a change in the spark-killer on the receiving relay are of assistance in improving transmission. Even with these expedients however, this system should not be considered for permanent operation at 60 speed.

22.0 Use of Regenerative Repeater.

While theoretically the use of regenerative repeaters in tandem on a circuit at appropriate distances will permit operation over circuits of any length, consideration must be given to their location in the circuit to give the best results. Regenerative repeaters are not only required in connection with the longer circuits. Cases arise in which the use of one or more regenerative repeaters are required in connection with circuits connecting points within a relatively small area. This is generally due to complication of the circuit, requiring that it be cut into two or three smaller circuits, in effect operating separately but repeating into each other.

GLOSSARY OF TERMS

Artificial Line.

An arrangement of resistance and capacity designed to balance the line circuit and the repeater at the distant end of the circuit. Used in connection with duplex operation. Corresponds to the network used in connection with a telephone repeater.

Automatic Key.

A key in which holding the key lever to one side produces a succession of dots and holding the key lever to the other side produces a steady marking signal. (Also known as a " vibroplex " key.)

Battery Tap.

A power lead to a telegraph circuit or telegraph repeater equipment. Normally provided with current-limiting resistance and heat coils.

Bias.

See under " Distortion."

Bias Corrector.

A parallel combination of resistance and capacity used in series with local circuits to improve signal wave shape.

" Break " Signal.

A signal transmitted from a receiving station to a sending station as an indication that a station on the circuit desires to interrupt the sending station. It is usually essential that a break signal be transmitted through repeater equipment without interruption by signals from the opposite direction and with minimum delay.

By-Pass Set.

An inductance coil arrangement for carrying telegraph signals around a telephone repeater at a point where intermediate composite sets are used with metallic telegraph operation.

Commutation.

Double Commutation.

The transmission of polar signals from a single battery by means of the simultaneous operation of two relay armatures which reverse the connections to the battery. Used in Bell System practice only in connection with the metallic telegraph system.

Single Commutation.

The transmission of polar signals by the use of a single relay armature and two batteries of opposite potential.

Composite Set.

A simple filter arrangement providing two grounded telegraph channels or a single metallic channel by superposition upon a side or phantom telephone circuit. Composite sets may be of the terminal or intermediate or combination type. A terminal composite set is used where both the telephone and telegraph circuits terminate or are repeated. Intermediate composite sets are used where the telegraph circuit goes through without a repeater but where the telephone circuit is terminated or is repeated. A combination composite set is one which has sufficient equipment to be used as either a terminal or an intermediate composite set. The change from one type of set to the other is made by operating a switch or inserting a plug in a jack.

Control Arrangements.

Break Contact Control.

Control circuit arrangements so connected that the machine involved, for example, a printer motor, will start when a control circuit is opened and stop when the control circuit is closed.

Make Contact Control.

Control circuit arrangements so connected that the machine involved, for example, a printer motor, will start when a control circuit is closed and stop when the control circuit is opened.

Polar Control.

Control arrangements for use with a relatively short circuit operated on a neutral basis permitting control over the line wire.

Selector.

A device responding only to a certain code signal and used to provide selective calling where several stations are permanently connected to the same line circuit.

Start-After-Break Control.

Control arrangements whereby all of the stations connected to a circuit will start on receiving a closed impulse following an open signal.

Crossfire.

Cross-induction between telegraph circuits.

Cutting Arrangements.

Arrangements enabling specific parts of a circuit to be detached or cut off from the remainder of the circuit at will, so that signals originating in the part of the circuit cut off will not be transmitted to the remainder of the circuit and vice versa.

Distortion.

The departure of the duration of received signals from that of the transmitted signals. Distortion of telegraph signals may be subdivided into certain components as follows:

Systematic Distortion.

The average distortion of a given part of a large number of successive regularly recurring signals.

Fortuitous Distortion.

The individual departure of one distortion from the average for a large number of successive signals.

Bias.

When the systematic distortion or a part of it is of such a nature that interchanging the marking and spacing polarities changes its sign but not its magnitude, the distortion is known as bias since it indicates a lack of symmetry in the circuit.

Characteristic Distortion.

When the systematic distortion or a part of it is such that it changes neither sign nor magnitude on interchanging the marking and spacing polarities, it is called characteristic distortion. Characteristic distortion results from the particular electric characteristic of the system and the magnetic and mechanical characteristics of the relays used.

Ground Potential or Earth Potential.

Potential differences occurring between office grounds.

Lining-Up

The operation of adjusting repeating and other relays, artificial lines and other parts of a telegraph circuit with a view to insuring the best possible operation of the circuit.

Lining-Up Distributor.

A machine used to send signals for lining-up purposes.

Noise-Killer.

A simple filter arrangement usually consisting of inductance and capacity designed to prevent the higher frequency components of the telegraph impulses from reaching the line circuit.

Operating Margin.

The degree to which the distortion of signals transmitted over a circuit may vary without causing unsatisfactory operation of the circuit. In the case of circuits possessing very little distortion the signals transmitted over the circuit can withstand a considerable amount of added distortion before becoming unsatisfactory. In such a case the circuit is said to have good operating margin.

Operation Terms.

Single (Used in speaking of service).

Service in which signals can be sent in either direction at will over the circuit but not simultaneously in both directions.

Duplex (Used in speaking of service).

Service in which signals may be transmitted in both directions over the circuit simultaneously.

Half-Duplex.

A circuit arrangement employing telegraph repeaters which are connected so that single service in either direction is obtained and so that at any time the receiving operator may "break" the sending operator and take control of the circuit.

Full-Duplex.

A circuit arrangement using telegraph repeaters so connected that signals may be transmitted simultaneously in both directions.

Grounded Circuit Operation.

Operation over a single straightaway circuit consisting of one metallic path for telegraph purposes with ground return.

Metallic Circuit Operation.

Operation of a circuit with a complete metallic path.

Marking and Spacing.

Terms applied to telegraph signals which have persisted from the time when signals were recorded upon a tape. A marking signal represents the condition with a closed key and a spacing signal the condition with an open key.

Heavy Signals.

Signals in which the marking impulses are prolonged while the spacing pulses are correspondingly shortened. (Marking bias.)

Light Signals.

Signals in which the spacing impulses are prolonged while the marking impulses are correspondingly shortened. (Spacing bias.)

Sixty Speed Operation.

Operation of a telephone typewriter circuit when characters are transmitted over the circuit at the rate of 360 characters or operations per minute which in normal traffic is equal to 60 words per minute. (Approximate line frequency 23 dots per second.)

Forty Speed Operation.

Operation of a telephone typewriter circuit when characters are transmitted over the circuit at the rate of 240 characters or operations per minute which in normal traffic is equal to 40 words per minute. (Approximate line frequency 15 dots per second.)

Telephone Typewriter Service.

Service in which messages are transmitted and received by means of printers.

Manual Operation or Service.

Service in which messages are transmitted by the manual operation of a key and are received on a sounder.

Upset Operation.

Operation in which signals are transmitted by upsetting the duplex balance of a duplex repeater which operates the receiving relay of the repeater. In ordinary practice a circuit having a duplex repeater at one or both ends is opened and closed by means of a telegraph key or printer distributor in series with the line circuit.

Potentiometer Arrangement.

The arrangement whereby a resistance is bridged from the telegraph circuit to ground on the line side of the battery tap resistance in order to reduce the potential applied to the line circuit. Used mainly in connection with the neutral and one-way polar telegraph systems.

Simplex Set.

An arrangement making use of a repeating coil having its line side closely balanced and providing one grounded telegraph channel by superposition on a pair of wires or on a phantom circuit.

Spark-Killer.

A combination of resistance and capacity bridged across contacts to prevent sparking and also in many cases to improve the wave shape of the signals transmitted by opening and closing the contacts.

Switching Systems.

One-Way Radial Switching System.

A switching arrangement providing one-way service from a main station to any or all of a number of outlying stations.

Two-Way Radial Switching System.

Arrangements providing two-way communication between a main station and any one of a number of outlying stations. If desired, the circuit is sometimes arranged so that the main station may broadcast to any or all of the outlying stations on a one-way basis.

Exchange System.

Arrangements whereby any two stations of a telephone typewriter network may communicate with each other through a central switching point.

Relays.

Neutral Relay.

A relay which will operate equally well on current of either polarity: usually having a soft iron core in which the pull of the electromagnet on the armature is partially counterbalanced by the pull of a spring which will return the armature to the back stop when the current in the operating winding falls off.

Polar Relay.

A relay equipped with a polarizing magnet and so designed that it will respond selectively to current of either polarity. That is, the armature will be operated to one position by current of one polarity and to the other position by current of the other polarity.

Repeaters.

Telegraph Repeater.

Equipment in which the signal is repeated by relay operation so that the permissible operating length of a circuit is increased.

Regenerative Repeater.

A type of repeater which can be used only in telephone typewriter service, in which the received signals are momentarily stored and are retransmitted from a distributor face so that the repeated signals are undistorted.

Reversals or "Dots."

A succession of dot signals (marks and spaces of uniform length) used for lining-up purposes.

Telegraph Channel.

A facility permitting the transmission of intelligence by means of telegraph signals.

Transmission.

Automatic Transmission or Sending.

The transmission of signals by means of a transmitter mechanism operated by means of a perforated tape.

Keyboard Transmission.

The transmission of signals by the operation of a keyboard.

Neutral Transmission.

The transmission of signals by opening and closing a direct current circuit.

Polar Transmission.

The transmission of signals by sending current of one polarity for one condition and current of the other polarity for the other condition.

Unbalance (Duplex Unbalance).

A condition allowing impulses to pass through the receiving relay of a duplex repeater when signals are transmitted from the repeater because the artificial line does not accurately balance the real line plus the distant repeater.