April 1, 1930. R. C. MATHES 1,752,498

TELEPHONE SYSTEM

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FIG. 1.

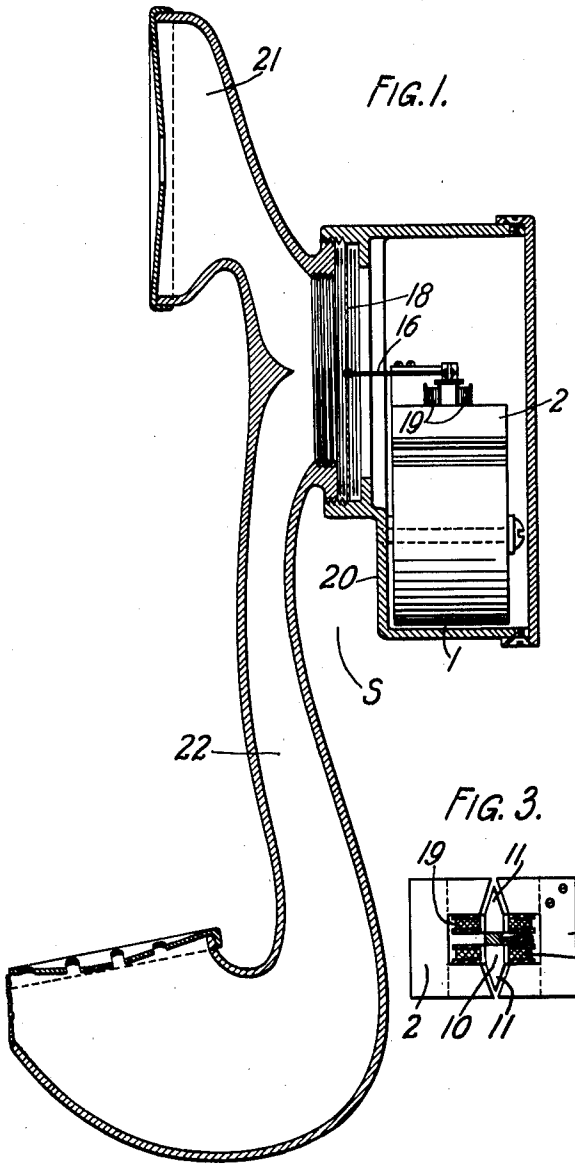


FIG. 2.

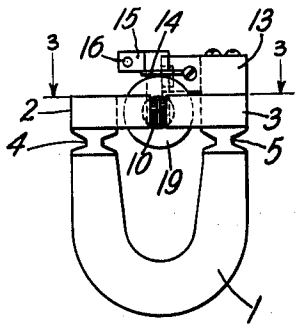
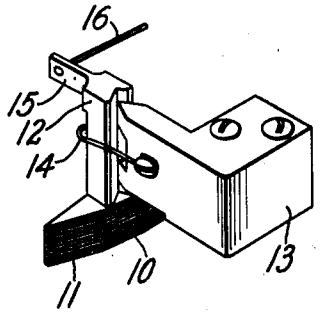


FIG. 3.

FIG. 4.



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FIG. 5.

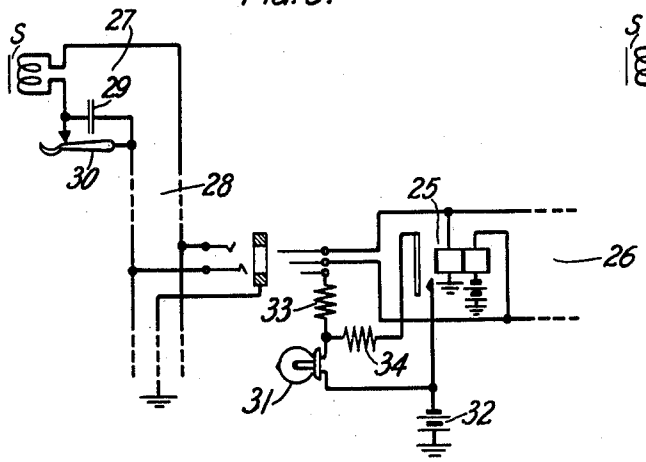


FIG. 6.

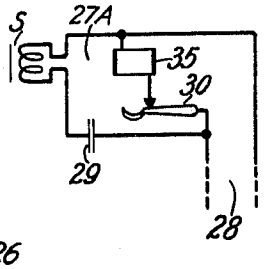


FIG. 7.

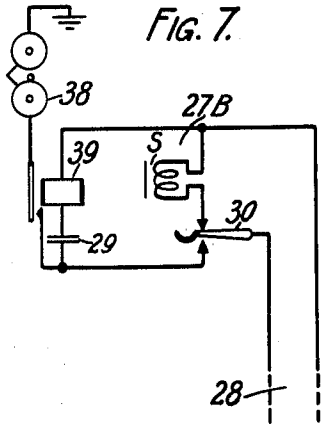
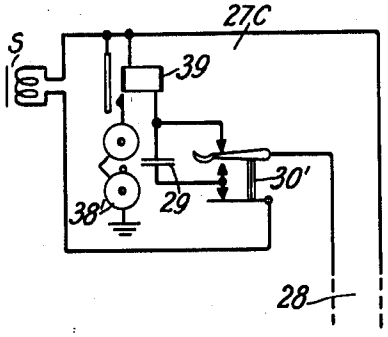


FIG. 8.



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FIG. 9.

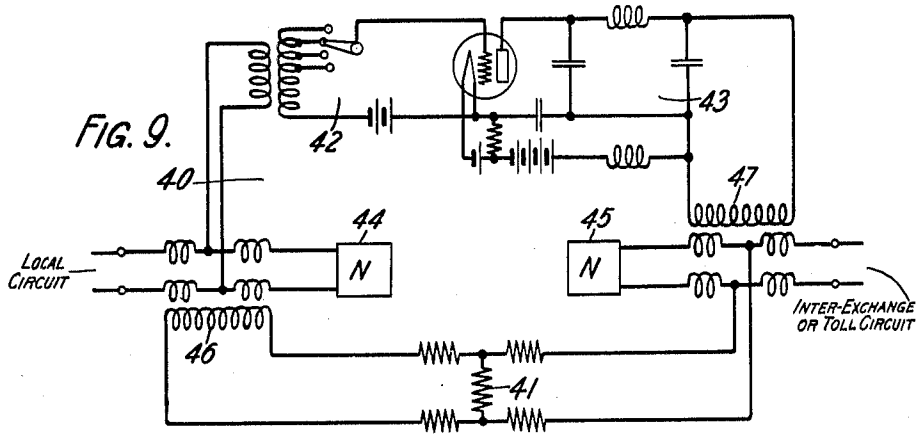


FIG. 13.

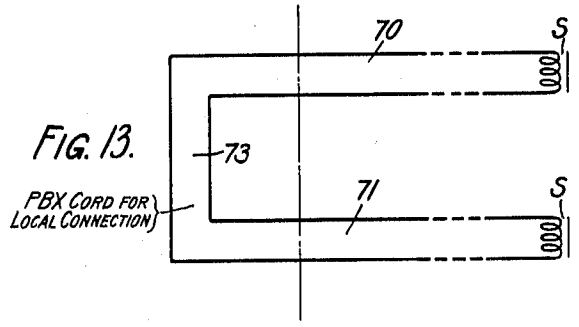
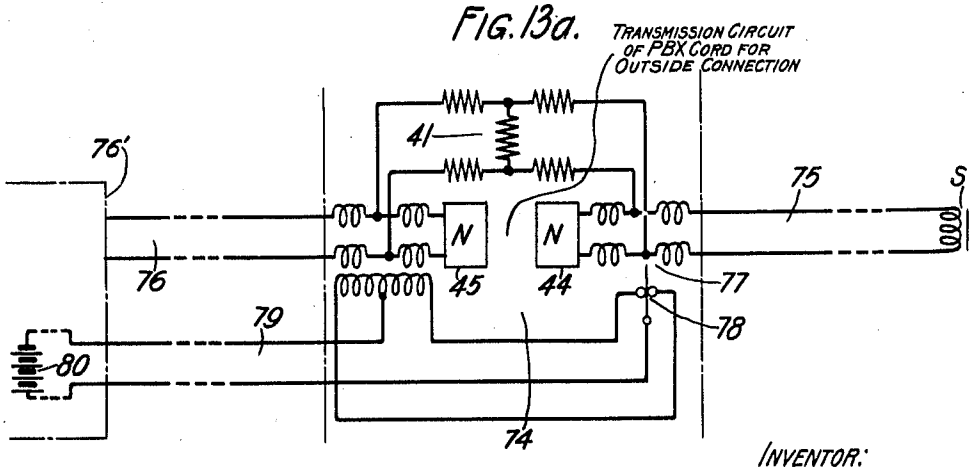


FIG. 13a.



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FIG. 10.

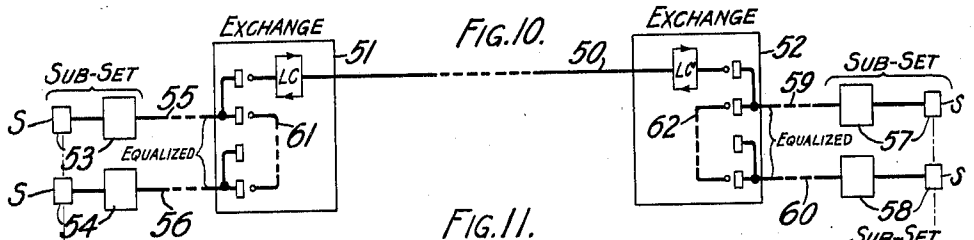


FIG. 11.

(PRESENT PRACTICE)

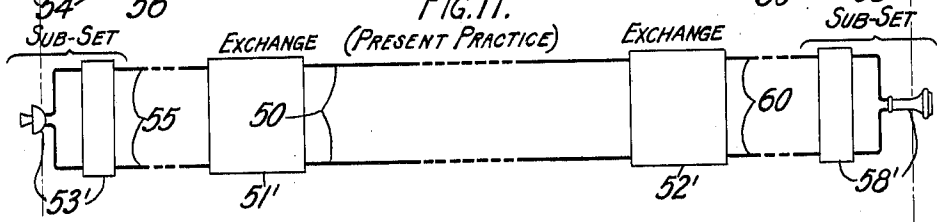
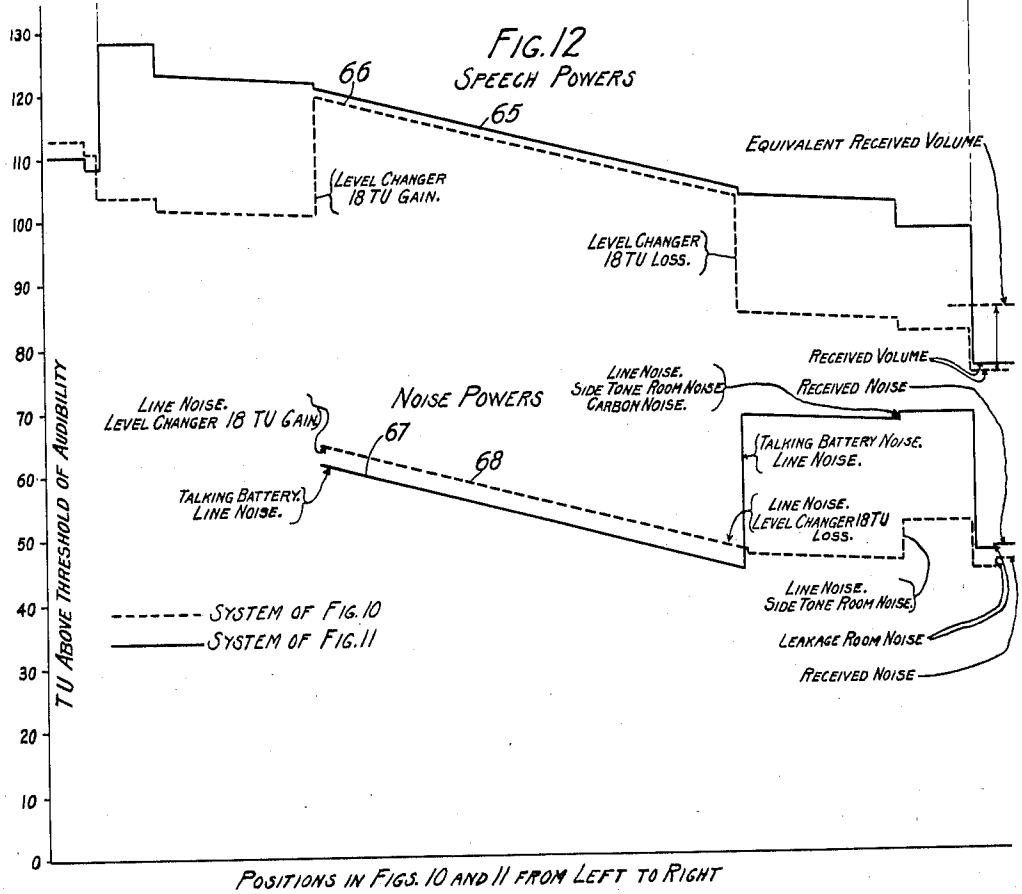


FIG. 12

SPEECH POWERS



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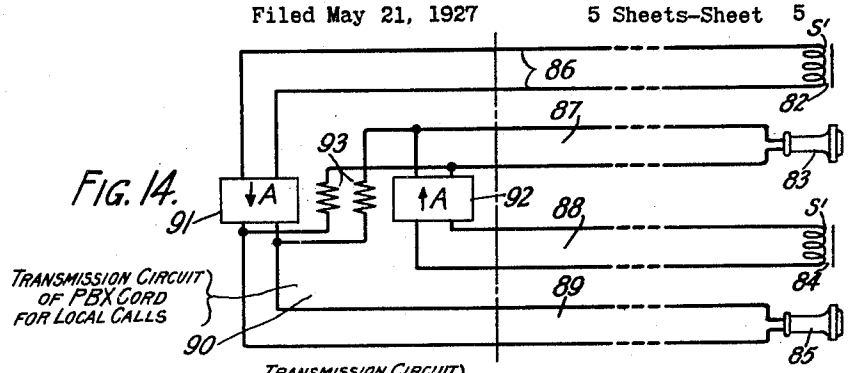


FIG. 14.

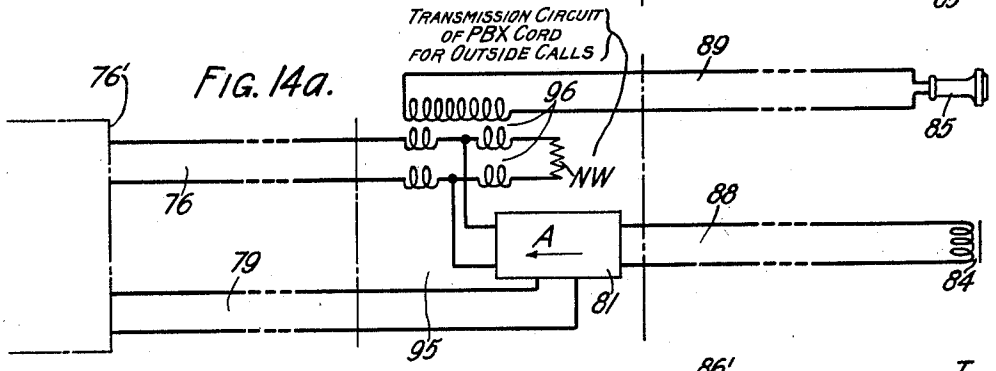


FIG. 14a.

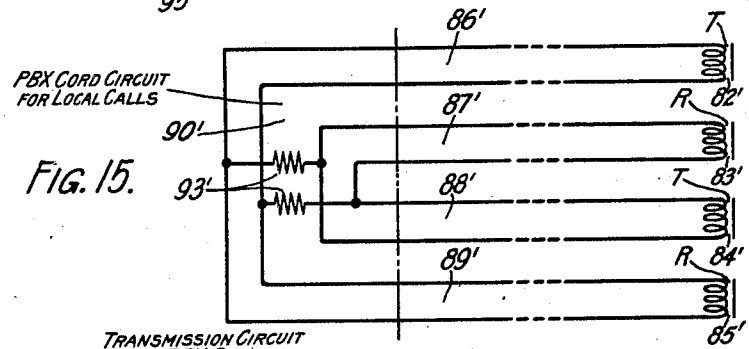


FIG. 15.

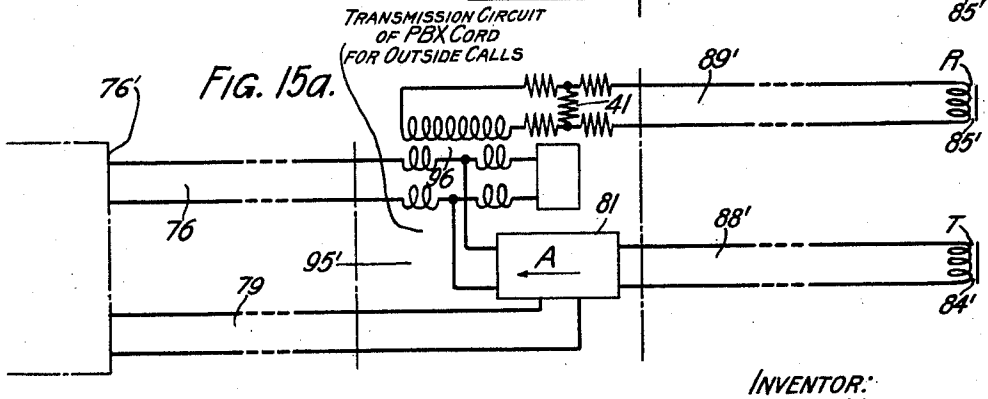


FIG. 15a.

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UNITED STATES PATENT OFFICE

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TELEPHONE SYSTEM

Application filed May 21, 1927. Serial No. 193,242.

This invention relates to telephony, and especially to control of energy levels in telephone systems.

An object of the invention is to obtain a high grade of telephonic transmission economically.

The invention in its preferred form is embodied in a system in which the transmitting and receiving means of each subscriber's telephone set is a single magnetic instrument giving much higher transmitting quality and receiving efficiency, but much lower transmitting efficiency, than standard commercial subsets. In signaling from one to another substation over subscribers' loops terminating at the same exchange, the electrical energy levels of the signals are much lower than standard practice, the noise on subscribers' lines being sufficiently small to render the low signal levels permissible; but since trunk circuits are more noisy than subscribers' lines, when subscribers' lines are connected through a trunk circuit there is employed at each end of the trunk circuit an energy level changer, of the general form of a 22-type repeater, which amplifies signals as they enter the trunk circuit from a subscriber's line and attenuates signals as they pass from the trunk circuit into a subscriber's line.

Other important objects and features of the invention will be made apparent hereinafter.

Fig. 1 is a side elevation, partly in section, of a telephone handset consisting of a magnetic transmitter and receiver of the type referred to above, the mouthpiece being shown partly broken away;

Fig. 2 is a rear elevational view of the electromagnetic elements shown in Fig. 1;

Fig. 3 is a cross section taken on line 3—3 of Fig. 2;

Fig. 4 shows the armature of the electromagnetic device and its suspension means;

Each of Figs. 5, 6, 7 and 8 is a diagram of a different substation circuit employing the transmitter and receiver of Fig. 1, Fig. 5 showing also a supervisory circuit including the substation loop and a portion of a cord circuit;

Fig. 9 shows a transmission level changer which may be employed in the system of Fig. 10;

Fig. 10 is a schematic showing of a telephone system embodying the invention;

Fig. 11 is a schematic showing of a telephone system such as is employed in standard commercial practice;

Fig. 12 is a set of level diagrams showing power levels of signals and of noise in the systems of Figs. 10 and 11;

Figs. 13 and 13A show a private branch exchange telephone system embodying the invention; Fig. 13 indicating a circuit arrangement for local connections or connections for communication between substations within the private branch exchange area, and Fig. 13A showing a circuit arrangement for outside connections or connections between a substation in the private branch exchange area and a central office;

Figs. 14 and 14A correspondingly show circuit arrangements for local connections and outside connections, respectively, in the case of another form of private branch exchange telephone system embodying the invention; and similarly, Figs. 15 and 15A show circuit arrangements for local connections and outside connections, respectively, in the case of still another form of private branch exchange telephone system embodying the invention.

A device for use as a telephone transmitter and receiver in a system embodying this invention may have its magnetic structure of the general type disclosed in Patent 1,709,571, issued April 16, 1929, on the copending application of H. C. Harrison, Serial No. 66,624, filed November 3, 1925. The magnetic structure comprises a permanent steady-field U-shaped magnet 1, on the ends of which are mounted pole pieces 2 and 3, which, however, are separated from direct connection with these ends by means of permalloy inserts 4 and 5. These inserts are provided to give uniform magnetic action from magnets varying in strength, as described and shown in the above mentioned copending application. They constantly limit the flux by virtue of being constantly saturated. Between

the pole pieces 2 and 3 is mounted the armature 10 having wedge shaped extensions 11 in position to be acted upon by the pole pieces 2 and 3. This arrangement is clearly shown in Fig. 3. The armature is secured to a mounting member 12 extended at right angle to the extensions 11. This member is provided with a groove registering with a knife-edged portion extending from the mounting block 13, which in turn is attached by means of screws to the upper surface of one part of the pole piece 3. The armature is held in place by a spring 14 secured at one end to the mounting block 13 and extending beyond and over the member 12 so as to press it against the knife edge on the block 13. The spring 14 is also used to balance the armature against the pull of field. The angular extension 15 on the member 12 is employed to transmit motions of the armature to the diaphragm 18 through the connecting rod 16. The energizing coils 19 for the armature are mounted on either side of the member 12 around the armature 10 so that the armature is free to move in and be influenced by electromagnetic fields produced by the coils when energized by fluctuating currents. A housing 20 is provided for enclosing this magnetic structure and an ear piece 21 and a mouthpiece 22 are associated therewith, as shown, for cooperating with the electromagnetic element to form a receiver-transmitter S.

When the coils 19 are energized by a fluctuating current, such as, for example, the talking current in ordinary telephone circuits, the varying magnetic flux component produced by these coils passes through the main portion of the armature 10, through the extensions 11, across the air gaps between extensions 11 and the pole pieces 2 and 3, and through those pole pieces. This flux tends to displace the armature from its balanced position between the pole pieces in accordance with the fluctuations of the energizing current. The armature actuates the diaphragm 18 to produce corresponding acoustic effects which are audible at the earpiece 21.

When sound waves delivered to the diaphragm 18 through the mouthpiece 22 cause actuation of the armature, corresponding electric current variations are produced in the coils 19, the device then serving as a magnetic telephone transmitter.

When this instrument is used as a receiver, it has a transmission loss less than the commercial receiver of standard practice by an amount of the order of 15 TU, for example. (A TU is a transmission unit, the significance of which is explained in "Transmission Circuits for Telephone Communication", by K. S. Johnson, published by D. Van Nostrand, New York, 1925.) When used as a transmitter, it has a transmission loss of the order of 7 TU, for example, whereas the commercial carbon button transmitter of standard practice on average loop has a gain of about 20 TU on toll circuits and the commercial receiver of standard practice has a transmission loss of about 22 TU when employed as a magnetic transmitter. Over the important part of the speech frequency range, the frequency response receiver characteristic of the device S is much more nearly flat than the characteristic of a commercial magnetic receiver or a commercial carbon button transmitter of standard practice. There results an improvement in articulation which is equivalent to a transmission volume gain of the order of 4 TU. When the device S is used as a transmitter, asymmetric distortion is substantially zero, or less than for a commercial carbon button transmitter by such an amount that there results an improvement in articulation equivalent to a transmission volume gain of about 5 TU. The overall transmitting-receiving efficiency in the case of a combination of two of the instruments S, one used as a transmitter and one used as a receiver, is nearer the sum of the separate efficiencies of the instruments than in the case of a combination of a carbon transmitter and the commercial receiver of standard practice, because of the flat frequency response characteristic of the new instruments. The transmitting-receiving efficiency of the combination of the new instruments is lower than that of the carbon transmitter and the commercial receiver by an amount of the order of a dozen TU. As the side tone for voice energy is lower by the same amount, a part of the loss in transmission efficiency is offset by increased talking volume, the subscriber raising his talking volume because of the low side tone. This increase in the energy level of the speech delivered to the transmitter is of the order of several TU, for example, and, with the increase in articulation due to the superior frequency response characteristics of the new instruments as transmitter and as receiver, approximately compensates for the dozen TU lower transmitting-receiving efficiency of the new instruments than of the standard commercial instruments. Moreover, when one of the new instruments is used both as transmitter and as receiver in a subset, the transmitting loss in the parts of the subset other than the transmitter can readily be made less than are the subset transmitting losses in the parts of the standard commercial subset other than its carbon button transmitter, and the receiving loss in parts of the new subset can readily be made less than are the subset receiving losses in the parts of the standard commercial subset other than its receiver. Circuit diagrams of subsets using the new instrument are discussed presently.

Even under circumstances in which it is not commercially practicable to introduce amplification between a transmitter of the substation of a subscriber's loop terminating at

one exchange and a connected receiver of the substation of another subscriber's loop terminating at the same exchange, the new instrument can be utilized as transmitter and receiver in the substations if the transmission equivalent of (or transmission loss in) the subscribers' lines is not materially greater than for unrepeatered connections in standard practice, provided the noise energy levels due to interference and cross-talk in the sub-loops are sufficiently low. In general, it is found that they are sufficiently low in the case in which the sub-loops terminate at a P. B. X. (private branch exchange) and also that these levels are sufficiently low or can readily be made sufficiently low in the case in which the sub-loops terminate at a central office (as distinguished from a P. B. X.). The most serious source of noise in sub-loops terminating at a central office is likely to be open wire or aerial cable exposed to power lines, especially when the subset is unbalanced to ground. The twisting of the conductors of the individual circuits amounts to almost perfect transposition giving protection against the induction of potentials between wires, but the noise is likely to enter through unbalances of the impedances of the talking conductors to earth, such as the unbalance created by the supervisory relays employed in standard commercial cord circuits which connect sub-loops. In order to reduce the noise on the sub-loops when the new subsets are to be employed, these unbalances to earth are preferably removed. For example, the creation of unbalance by the supervisory relay is preferably avoided by employing high inductance shunt supervisory relays each having its winding earthed at its mid-point as shown in the case of supervisory relay 25 in Fig. 5.

Fig. 5 shows a portion of a cord circuit 26 connected to a substation 27 by a line 28. The device S serves not only as the transmitter and receiver of the subset, but also as a path for the supervisory current which operates relay 25, and as a call signal. Preferably the frequency of the calling generator (not shown) which is used to supply the current for operating device S as a call signal is a frequency in the voice range, as for example 500 cycles per second, since the device S responds more readily to such frequency than to the lower frequency commonly used to operate subscribers' ringers. The calling current transmitted to station 27 over line 28 passes through a condenser 29 and the device S, and is preferably much smaller than the usual ringing currents. When the subscriber lifts the hand-set S to respond to a call, a receiver operated switch 30 closes a circuit for energizing the supervisory relay 25 which thereupon as is usual, causes a supervisory lamp 31, in series with a battery 32 and a resistance 33, to be shunted by a resistance 34 for dimming the lamp as long as switch 30 remains closed. Preferably, the relay 25 is a high resistance relay and the supervisory current passing through device S much smaller than the usual supervisory relay operating currents. The substation contains no transmission devices, other than device S, which can cause any important transmitting loss or receiving loss for telephonic transmission.

Fig. 6 shows a substation 27A in which the device S is used as a transmitter, a receiver, and a call signal, as in Fig. 5, but carries no supervisory current. The switch 30, when closed allows supervisory current to pass through choke coil 35.

Fig. 7 shows a substation 27B in which the device S serves as transmitter, receiver and supervisory current path, but in which a separate call signal 38 shown as the usual low frequency ringer ~~is~~ employed. The ringer is controlled by a relay 39 which has its winding connected in series with condenser 29 across the line 28. When switch 30 is in depressed condition, low frequency ringing current transmitted to station 27B over line 28 passes through condenser 29 and the winding of relay 39, energizing the relay and therefore causing ringer 38 to be energized. When the subscriber lifts the handset S to answer the call, switch 30 opens the circuit of relay 39 and ringer 38 and connects the device S across line 28 so that talking current and supervisory relay operating current can pass through device S.

Fig. 8 shows a substation 27C in which the device S serves only as transmitter and receiver, a separate call signal 38′ (shown as the usual ringer) being employed. Ringer 38′ is controlled by a low frequency ringing current responsive relay 39 the winding of which serves as a supervisory current path. When the handset S rests on a switch 30′, ringing current transmitted to station 27C over line 28 passes through the winding of relay 39 and the condenser 29, which are connected in series across line 28 by the middle contact of switch 30′. Thereupon the armature of relay 39 connects ringer 38 across line 28. When the subscriber lifts subset S to answer the call, switch 30′ moves to its upper position, to break the circuit through the winding of relay 39 and the condenser 29, at its middle contact, and to close a supervisory current path through the winding of relay 39, at its upper contact, and to close a talking current circuit across line 28 through the device S, the lower contact of switch 30′, the condenser 29 and the upper contact of switch 30′, all four in series.

As pointed out in application Serial No. 66,624 mentioned above, the device S can be given the transmission characteristic of a band filter. Therefore, in cases in which it is not desired to use the device S as a

call signal, as for example in the case of the subset of Fig. 7 or the subset of Fig. 8, the pass range of the device can be so chosen that the device will greatly attenuate current of the frequency used for operating the call signal, to reduce danger of acoustic shock due to ringing in the ear. For instance, a frequency of 16 cycles per second may be used to operate the call signal, and the pass range of the device S may be a frequency band lying above the call signaling frequency and including the important voice frequencies.

A form of the invention shown in Fig. 10 employs energy level changers LC and LC' which may be for example, of the form of level changer 40 of Fig. 9. The device 40 is an ordinary 22-type repeater circuit except that the transmission path in one direction through the device includes an attenuating artificial line 41 instead of an amplifier and filter path, such as electric space discharge amplifier 42 and filter 43 in the path in the other direction through the device. The device 40 includes impedance balancing networks 44 and 45 for balancing the impedances of a local circuit and a trunk circuit, respectively, between which the device is to be connected, and includes three-winding transformers 46 and 47 for associating the attenuator 41 and the amplifier 42 and filter 43 with the two circuits. In Fig. 10, lever changer LC may amplify transmission passing through it from left to right and attenuate transmission passing through it from right to left, and level changer LC' may amplify transmission passing through it from right to left and attenuate transmission passing through it from left to right. A trunk circuit, as for example a toll circuit or an inter-exchange trunk circuit 50, extends between two exchanges 51 and 52, which may be, for example, central offices in the same city or in different cities. Subscribers' stations such as 53 and 54 are connected to exchange 51 by subscribers' lines such as 55 and 56 respectively. Subscribers' stations 57 and 58 are connected to exchange 52 by subscribers' lines 59 and 60 respectively. The substation, such as 53, 54, 57 and 58, may be, for example, any of the substations 27, 27A, 27B and 27C shown in Figs. 5 to 8.

Cord circuits such as 61 are employed when connection is to be established between subscribers' lines, such as 55 and 56, terminating at exchange 51; and similarly, cord circuits such as 62 are employed for connecting subscribers' lines, such as 59 and 60, terminating at exchange 52. These cord circuits have no talking battery, since the substations have magnetic transmitters S which do not require a supply of energizing current.

When one of the subscribers' lines such as 55 and 56, terminating at exchange 51 is to be connected to one of the subscribers' lines, such as 59 and 60, terminating at exchange 52, the connection is made through a trunk circuit such as 50, a level changer, such as LC, being included in circuit between the trunk circuit and the subscriber's line which terminates at exchange 51, and a level changer, such as LC', being included in circuit between the trunk circuit and the subscriber's line which terminates at exchange 52. Again no talking battery is in circuit.

Fig. 11 shows schematically a telephone connection which represents standard commercial practice. It comprises standard commercial subsets 53' and 58' connected by subscribers' lines 55 and 60 and a trunk circuit 50 which connects to line 55 at a central office 51' and to line 60 at a central office 52'.

In Fig. 12 the full line 65 is a speech power or energy level graph and the full line 67 is a noise energy level graph, for transmission from subset 53' to subset 58' in Fig. 11; and the dotted line 66 is a speech energy level graph, and the dotted line 68 a noise energy level graph, for transmission from subset 53 to subset 58 in Fig. 10. All of the energy level graphs are for a case in which the lines 55 and 58 are each a one mile loop of No. 22 gauge cable (which is commonly known as an average loop) and the trunk circuit 50 is a toll line of 10 TU loss connected at each end to one of the exchanges by a toll switching trunk of 3 TU loss, giving a total transmission loss of 16 TU (and known as the average toll connection) between exchanges. The energy level graphs 66 and 68 are for a case in which the energy level changer LC gives a gain of 18 TU from line 55 to trunk circuit 50, and energy level changer LC' gives a loss of 18 TU from trunk circuit 50 to line 60. Each point in the energy level graphs corresponds to the point directly above it in the system of Fig. 10 or Fig. 11. The ordinates of the energy level graphs are TU above the threshold of audibility. The threshold of audibility is approximately a level of acoustic power the mechanical equivalent of 2.5×10^{-10} micro-watts (assuming a frequency distribution of energy approximating that of an average voice). Thus the ordinates represent power, or energy per unit of time. The noise distribution to the left of the exchanges 51 and 51' is neglected.

The loss represented in graph 65 as occurring at a point reached just before the transmitter of subset 53', is acoustic loss due to the fact that not all of the acoustic energy of the speaker's voice reaches the transmitter button. The graph shows a large gain in the transmitter, followed by a loss in part of the subset other than the transmitter, (including the receiver), a loss in the line 55, a loss in the exchange 51' (due to a repeating coil cord circuit at a toll position through which the connection passes), a loss in the toll switching trunks and toll line, a loss in the exchange 52' (due to a repeating coil cord circuit at a

toll position through which the connection passes), a loss in line 60, a loss in part of the subset other than the receiver, (including the transmitter), and a large loss in the receiver, the final level represented in the graph being the level of the acoustic energy delivered by the receiver.

In graph 66 there is represented an acoustic loss before the transmitter S of subset 53 is reached, a loss in the transmitter, a small loss in the part of the subset other than the transmitter, a gain of 18 TU in the level changer LC, a loss in the toll switching trunks and toll line, a loss of 18 TU in the level changer LC′, a loss in the line 60, a small loss in the part of subset 58 other than receiver S, and a loss in receiver S, the final level of the graph 66 representing the acoustic energy delivered by the earpiece of the receiver. A vertical line at the right hand end of graph 66, having an arrow-head at each end, represents an equivalent gain of 9 TU, due to the reduced asymmetric and frequency distortions in the transmitter S of subset 53 and the reduced frequency distortion in the receiver S of subset 58 compared to the distortion in the transmitter of subset 53′ and the distortion in the receiver of subset 58′.

In the noise level graphs 67 and 68 the noise distribution to the left of exchange 51 or 51′ is neglected, and the line noise entering the system for which the diagram is drawn is represented as having entered the system partly in the portion of the system at or to the left of the exchange 51 or 51′, and entering the system partly at the exchange 52 or 52′, and partly at the subset 58 or 58′. The power values given to the parts of the line noise represented as entering at these parts of the system are such as would produce at the receiver the same effect which would be produced there by the line noise which would actually enter the system to the left of the exchange 51 or 51′ and at any portions of lines 50 and 60 exposed to interference or crosstalk.

Graph 67 shows, at exchange 51′, a noise level due to talking battery noise and line noise. Attenuation of noise by the trunk circuit 50 is indicated by the sloping portion of the diagram between exchanges 51′ and 52′. Entry of talking battery noise and line noise at exchange 52′ is indicated by the vertical portion of diagram 67 below the exchange. Attenuation of noise by line 60 is indicated by the sloping portion of the graph between exchange 52′ and subset 58′. The graph indicates entry of noise into the system at the portion of subset 58′ other than the receiver, this noise being line noise, side tone room noise from the transmitter of subset 58′, and carbon noise from that transmitter. A large attenuation of noise by the receiver of subset 58′ is shown by the vertical portion of the graph below the receiver, and just to the right of that portion a leakage room noise is indicated, to represent noise leaking between the receiver and the listening ear, from the room.

Graph 68 shows, at exchange 51, a noise level due to 18 TU amplification of line noise reaching the input of the amplifying device in level changer LC. No talking battery noise is introduced at the exchange, since the magnetic transmitter S of subset 53 does not require a talking battery. Attenuation of noise by the trunk circuit 50 is indicated by the sloping portion of the graph between exchanges 51 and 52. The vertical portion of the graph below level changer LC′ represents 18 TU attenuation of noise by the level changer and also the entry of approximately 18 TU more noise at the output side of the level changer. No talking battery noise is introduced at the exchange 52, since the magnetic transmitter S of subset 58 does not require a talking battery. Attenuation of noise by line 60 is indicated by the sloping portion of the graph between exchange 52 and subset 58. The graph indicates entry of noise into the system at the portion of the subset other than the receiver S, this noise being line noise and side-tone room noise resulting from acoustic noise entering the mouthpiece of the device S of subset 58. No carbon noise is introduced at the subset 58, since the transmitter S of the subset is a magnetic transmitter. Attenuation of noise by the receiver of subset 58 is shown by the vertical portion of the graph below the receiver, and just to the right of that portion a leakage room noise is indicated, to represent noise leaking between the receiver and the listening ear, from the room.

In order that the combined transmission equivalents of the two level changers LC and LC′ for transmission in either direction may be less than zero, in each of the level changers LC and LC′ there may be employed, instead of an attenuator which attenuates transmission in one direction by the same amount that the amplifier of the level changer amplifies transmission in the opposite direction, an attenuator which introduces an amount of attenuation less than the amplification, or each level changer may be an ordinary 22-type repeater, preferably adjusted to give unequal gains in opposite directions.

In systems such as that shown in Fig. 10, not only do the level changers reduce deleterious noise effects, but the attenuators in the level changers or the differences between the transmission efficiencies for opposite directions, in the level changers, make the high efficiency receiver S, which is necessarily of high efficiency in order to be usable on direct (non-amplifying) connections of the low energy level circuits, usable also when the low energy level circuits are connected to the circuits which must have high signal energy

level because they have high noise energy level. Further, the attenuation in the attenuators, or the asymmetric transmission efficiency of the level changers, facilitates employing the low-distortion transmitter, notwithstanding its high receiving efficiency, as a combined transmitter and receiver for connections in which high levels of signal energy must be used in order to reduce deleterious effects of noise.

If it be attempted to employ the ordinary telephone receiver as a transmitter for subscribers' stations in the telephone plant, the very poor transmitting efficiency of the instrument necessitates use of an excessive degree of amplification. However, the use of the device S as a transmitter and as a receiver obviates the necessity for an excessive amount of amplification and brings the use of the magnetic transmitter within the realm of commercial practicability. As has been pointed out above, not only has the device S substantially higher transmitter efficiency and receiver efficiency than the ordinary telephone receiver, but the intelligibility of a connection employing two of the devices S, one as transmitter and one as receiver, is increased an amount equivalent to a transmission gain of about 9 TU due to the relative freedom of the devices from frequency distortion and asymmetric distortion.

If a level changer introduces a gain in transmission in one direction at least as great as the losses which it introduces in transmission in the opposite direction, it may be said to have a net gain, or to introduce net amplification. Introducing amplification in connections between subscribers' stations, for example by means of level changes at central offices, may be helpful by introducing net amplification as well as by rearranging the speech level in various links in the speech circuit according to the amount of interference present. The net amplification which can be introduced by two-way level changers is much smaller than would be possible with one-way transmitting amplifiers, because two-way level changers with net gain have a tendency to sing. Therefore, the use of the transmitter (S) having higher efficiency than the ordinary receiver used as a transmitter, and especially the use of the high efficiency receiver (S), facilitates the use of the two-way transmitting type of level changers in connections between subscribers' sets in cases in which net gain in level changers is desired in order to give adequate overall transmission efficiency from subscriber to subscriber (and also in cases in which net gain is desired for reducing deleterious effects of receiver loop noise or room noise, as pointed out hereinafter). The practicability of using level changers of the two-way transmitting type is a matter of importance, since if a level changer is of the two-way transmitting type only two conductors are required to connect it to a subscriber's station for two-way transmission and therefore it can be located at a distance from the subscriber's set (as for example at a P. B. X. switchboard or at a central office) without necessitating use of 4-wire circuits of considerable length; and since moreover, in case a single instrument is to serve both as a transmitter and as a receiver, it cannot be connected to an amplifier circuit or level changer which transmits in but one direction, and therefore if amplification is to be employed a two-way transmitting amplifier circuit or level changer must be used; and since, moreover, in cases in which level changers for use in connections between substation lines terminating at different exchanges are to be omitted from circuit when one of the substation lines is to be connected to a substation line terminating at the same exchange, the latter connection can be a two-wire connection if the substation lines involved are two-wire lines, whereas it must be a four-wire connection, with the consequent complication of the exchange switchboard, if the substation lines involved be four-wire lines.

By having level changers introduce net amplification in a circuit connecting two substations, discrimination, to the extent of the net gain, is obtained against noise entering the system through the portion of the circuit beyond the point at which the net gain is introduced. For example, by securing net gain in the level changers LC and LC′ of the system of Fig. 10, discrimination in favor of signals is obtained not only against noise entering the system between the level changers but also against noise entering the system through the low energy level path which connects the high energy level path with the receiver.

When net gains are secured in level changers in central offices, as for example the level changers LC and LC′ in the system of Fig. 10, an advantage against room noise is obtained which would not follow from increasing overall efficiency by raising transmitter efficiency; for in the latter case the side tone efficiency is also increased.

The impedance of the subscribers' loops in systems such as that of Fig. 10 may be carefully equalized, to facilitate obtaining accurate impedance balances at the level changers, so that the net gains of the level changers may be increased. With accurate impedance balances, the apparent transmission equivalents of the sub-loops can be reduced to zero, or even a gain obtained for transmission over these circuits.

Either of the exchanges 51 and 52 in Fig. 10 may be a private branch exchange, instead of a central office exchange. The trunk circuit 50 may then be an inter-exchange trunk between the P. B. X. and the central office.

Figs. 13 and 13A show transmission circuits of a P. B. X. system employing telephone sets S at the subscribers' stations. In Fig. 13 two such magnetic transmitter-receivers S are connected to subscribers' lines 70 and 71 which terminate at the P. B. X. switchboard and are there connected directly together by a cord circuit 73 for local communication, between the two sets S. The transmission circuit of a cord circuit 74 for making outside connections is shown in Fig. 13A, wherein the cord circuit 74 is represented as connecting the line 75 to a talking trunk 76 extending from the P. B. X. switchboard to the central office 76'. The cord circuit 74 is a level changer which is like that of Fig. 9 except that, instead of the vacuum tube amplifying device and the electrical filter, there is employed a mechanical carbon button type of amplifying device 77, the hybrid coil windings associated with line 75 and its balancing network 44 preferably being part of the device and operating a push-pull carbon button 78. A battery trunk 79 supplies current for the carbon button from a battery 80 at the central office.

If desired, the level changers LC and LC' in Fig. 10 may be of the type of device 74. Also, if desired the level changer 40, instead of the level changer 74, may be employed in Fig. 13A.

While the P. B. X. is a less desirable point, as regards maintenance for a level changer, than the central office, the location of the level changer at the P. B. X. is preferable from the point of view of reducing deleterious effects of noise.

In the P. B. X. system of Figs. 13 and 13A, the speech levels in the subscribers' loops are much lower than standard practice, being for example of the same order of magnitude as those in Fig. 12 for loops 55 and 60; and the speech levels in trunk 76 are, for example, approximately the same as in standard practice, the level changer 74 performing functions similar to the level changer LC of Fig. 10.

As P. B. X. substation loops are in general shorter and less exposed to interference conditions than central office substation loops, the noise effects which must be guarded against in the lines in which the signal energy levels are low, will be less in the case of the P. B. X. substation loops. Moreover, magnetic transmitters are desirable in P. B. X. substations for the reason that the use of carbon transmitters in such service entails disadvantages, on account of the problem of battery supply, additional to those entailed by the use of carbon transmitters in private telephone sets which have their substation lines terminate at a central office; for when battery current for energizing substation microphones is fed to the P. B. X. over cable pairs the extreme voltage fluctuations are greater than in the case of private telephones connecting directly to the central office. It is easier to supply battery current to a P. B. X. to energize the level changers such as 74 than it would be to energize the microphones, because all of the level changers can be at one point, so that they will make equal drains on the current supply, whereas the individual substation loops in present P. B. X. practice differ greatly in their impedances, the shorter ones shunting current away from longer ones to a serious degree. Thus the system of Figs. 13 and 13A greatly simplifies the P. B. X. battery supply problem. The incorporation of the instruments S in P. B. X. systems is particularly favored by the fact that the average loss in substation lines terminating at P. B. X. switchboards is small, as compared to the loss in, for example, subscribers' lines terminating at central offices.

Figs. 14 and 14A show transmission circuits of a P. B. X. system employing a one-way amplifier 81, at the private branch exchange, for outside calls. The amplifier 81 may be an ordinary electric space discharge tube amplifier, for example. Four wires extend from the exchange to each subset, the transmitter being separate from the receiver at each subset. The transmitters S' are like the instruments S described above, except that only one acoustic channel, the one to the mouth piece, is provided. The receivers are of the ordinary type. The talking trunk 76 is shown, as in the case of Fig. 13A, and also the battery trunk 79, which in the case of Fig. 14A may supply energizing current, for example, unidirectional filament heating current, for amplifier 81. In Fig. 14, one subset comprises a transmitter 82 and a receiver 83 and another subset comprises a transmitter 84 and a receiver 85. The instruments 82, 83, 84 and 85 are connected to the private branch exchange by two-wire lines 86, 87, 88 and 89, respectively. A cord circuit 90 at the P. B. X. switchboard contains a one-way amplifier 91 for connecting lines 86 and 89 and a one-way amplifier 92 for connecting lines 88 and 87. The directions in which these amplifiers transmit are indicated by the arrows in the drawing. Impedances 93, connecting the output sides of the amplifiers, preferably provide a small fixed amount of side tone, but may be removed if it is desired to have the circuit for local connections absolutely anti-side tone.

The transmission circuit of a cord 95 for making outside connections is shown in Fig. 14A. The cord 95 comprises the one-way amplifier 81 pointed for transmission in the direction indicated by the arrow in the drawing, and a three-winding transformer, or hybrid coil 96, and its balancing network balancing the impedance with which the trunk circuit 76 faces the hybrid coil. The

cord 95 is adapted to connect a transmitter line, such as 88, and a receiver line, such as 89, of a subset such as that comprising transmitter 84 and receiver 85, to a trunk circuit such as 76, so that the amplifier amplifies signals from the transmitter and delivers them to the trunk circuit, and the amplifier and the receiver line are in conjugate relationship to each other, and signals from trunk circuit 76 are received in receiver 85. The degree of side tone desired may be adjusted by adjusting the balance of the hybrid coil or the degree of accuracy with which the impedance of the trunk circuit is balanced by its balancing network.

In Figs. 14 and 14A the transmission, except for the initial run from the transmitters to the one-way amplifiers, may be kept at the volume levels now obtaining in standard commercial practice, so that receiver elements having a volume efficiency in accordance with standard commercial practice may be employed. From the transmitters to the amplifiers the volume levels may be the same as in Fig. 13A. Different lengths of loops between the subsets and the trunk circuit can be equalized by merely adjusting the gain of the repeater.

Figs. 15 and 15A show transmission circuits of a P. P. X. system employing a one-way amplifier 81 and an attenuator 41 at the private branch exchange, for outside calls. Four wires extend from the exchange to each subset, the transmitter being separate from the receiver at each subset. The transmitters T are the same as the transmitters S' described above in connection with Figs. 14 and 14A. The receivers are like the instruments S described above, except that only one acoustic channel, the one to the earpiece, is provided. The talking trunk 76 and the battery trunk 79 are shown, as in the case of Fig. 14A. In Fig. 15, one subset comprises a transmitter 82' and a receiver 83' and another subset comprises a transmitter 84' and a receiver 85'. The instruments 82', 83', 84' and 85' are connected to the private branch exchange by two-wire lines 86', 87', 88' and 89', respectively. At the exchange a cord circuit 90' connects lines 86' and 89' directly together, and lines 88' and 87' directly together, or local communication between the two subsets to which these lines are connected. Impedances 93' preferably provide a small fixed amount of side-tone, but may be removed if it is desired to have the circuit for local connections absolutely anti-side tone.

The transmission circuit of a cord 95' for making outside connections is shown in Fig. 15A. The cord 95' is like the cord 95 of Fig. 14A, except that cord 95' contains an attenuator 41 for inclusion in circuit between the series winding of the hybrid coil 96 and the receiver line, such as 89', to which that winding supplies current. The cord circuit 95' is adapted to connect the transmitter 84' and the receiver 85' to the trunk circuit 76 as the cord circuit 95 connects the transmitter 84 and the receiver 85 to the trunk circuit.

In Figs. 15 and 15A, since the receivers have high efficiency, and the transmitters have high efficiency as compared to the efficiency of an ordinary commercial magnetic receiver used as a transmitter, the volume levels of transmission in the transmitter lines and the receiver lines of the P. B. X. may be the same low levels that are employed in the substation lines in Figs. 13 and 13A. No amplifier is used for local calls, and but a single amplifier is needed for outside calls. The volume level of the signals in trunk 76 may be as in Fig. 14A.

The use of the transmitter with substantially higher transmitting efficiency than the ordinary receiver has when used as a transmitter, facilitates obtaining from a magnetic transmitter a signal energy level high enough to put on, for example, a trunk from a private branch exchange, without requiring an amount of amplification which would be excessive, and therefore facilitates rendering commercially practicable the installation of, for example, a one-way amplifier at a private branch exchange, for amplifying signals for transmission to a central office.

While the magnetic type of transmitter is specifically described hereinbefore, as particularly suitable for practicing this invention, other forms of transmitting devices which are suitable as to energy output and quality may be used and the claims are drafted to protect such arrangements.

What is claimed is:

1. A telephone system comprising telephone exchanges, subscribers' lines connected to said exchanges, trunk circuits extending between said exchanges, means included in said exchanges for connecting said subscribers' lines to said trunk circuits to form telephone transmission circuits, and means for maintaining a lower signal energy level on said subscribers' lines than on said trunk circuits, whereby advantage is taken of lower noise energy level on the subscribers' lines than on the trunk circuits, said last mentioned means including energy level changers and means for bringing said energy level changers into the telephone transmission circuits when a subscriber's line is connected to a trunk circuit.

2. The method of transmitting signals to a telephone substation through a zone of disturbance, which comprises raising the transmission level of the signals upon their entry into said zone, lowering the transmission level of the signals upon their departure from said zone, and maintaining the energy level of the signal transmission entering said substation, but originating outside of said station, normally less than a hundred transmission units

above the threshold of audibility by an amount as great as approximately a dozen transmission units.

3. In combination, a telephone substation, including a telephone receiver having a transmission loss less than a loss of twenty transmission units by as many as approximately a dozen transmission units, circuits of classes having substantially different intensities of noise, a receiver circuit connected to said receiver, means for connecting said receiver circuit to one of said first mentioned circuits in which the noise intensity is higher than in another, lumped attenuating means included in said first means for attenuating transmission from said one circuit to said receiver, and means having substantially zero transmission equivalent for connecting said receiver circuit to one of said first mentioned circuits in which the noise intensity is less than in another.

4. A telephone system comprising a central office, subscribers' loop circuits terminating at said office, and means at said office for amplifying energy transmitted from said circuits while maintaining the level of the amplified energy normally substantially as low as a hundred and twenty transmission units above the threshold of audibility, and for attenuating energy transmitted to said circuits to a level normally less than a hundred transmission units above the threshold of audibility by as many as approximately a dozen transmission units.

5. A telephone system comprising a central office, a substation including a magnetic telephone transmitter giving a transmission loss, a substation including a telephone receiver having a transmission loss less than a loss of twenty transmission units by as many as approximately a dozen transmission units, a two-conductor circuit connecting the first mentioned substation to said office, a two-conductor circuit connecting the second mentioned substation to said office, and an energy amplifying, two-way transmitting level changer connecting said circuits at said office.

6. A telephone transmission system comprising a substation including a magnetic transmitter, a substation including a telephone receiver having a transmission loss less than twenty transmission units by as many as approximately a dozen transmission units, a switchboard, a circuit connecting the first mentioned substation to said switchboard, a circuit connecting the second mentioned substation to said switchboard, means at said switchboard for connecting said circuits, a circuit shunted at said switchboard, across said first mentioned circuit, a source of supervisory signaling electromotive force and a high inductance, low current supervisory relay included in said shunt circuit, and a connection to earth from substantially the midpoint of said shunt circuit with respect to its impedance.

7. A telephone system comprising subscribers' stations, telephone exchanges, subscribers' circuits connecting said subscribers' stations to said exchanges, trunks extending between said exchanges, means included in said exchanges for connecting said subscribers' circuits to said trunks to form telephone transmission circuits, means for maintaining a lower signal energy level on said subscribers' circuits than on said trunks, said last mentioned means including energy level changers, means for bringing said energy level changers into the telephone transmission circuits when a subscriber's line is connected to a trunk, and a magnetic transmitting and receiving element in each of said substations, said element having a magnetic circuit, said magnetic circuit comprising movable and stationary magnetic members with an air gap therebetween, and one of said members tapering in cross-section adjacent said gap.

In witness whereof, I hereunto subscribe my name this 12th day of May A. D., 1927.

ROBERT C. MATHES.