

April 16, 1929.

J. S. JAMMER

1,709,076

MULTIPLEX SIGNALING SYSTEM

Filed Sept. 24, 1924

3 Sheets-Sheet 1

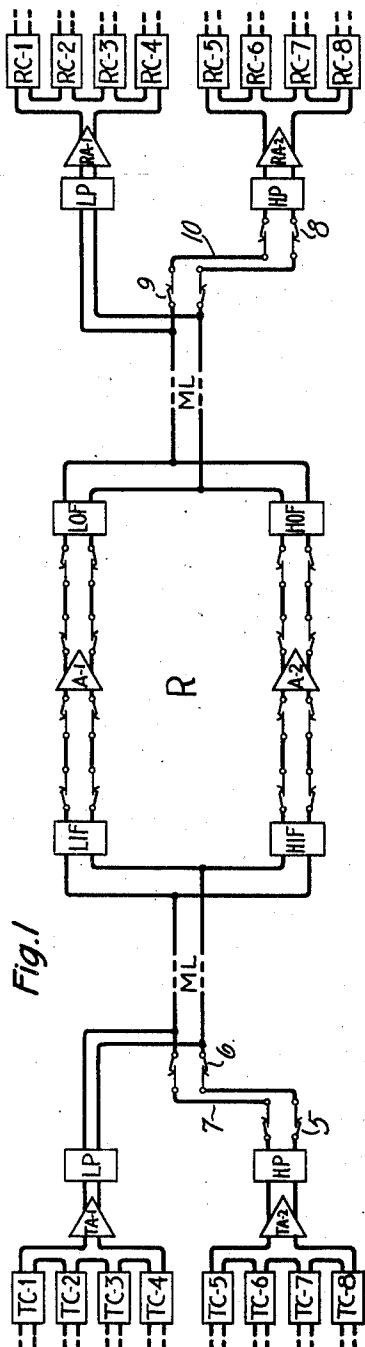
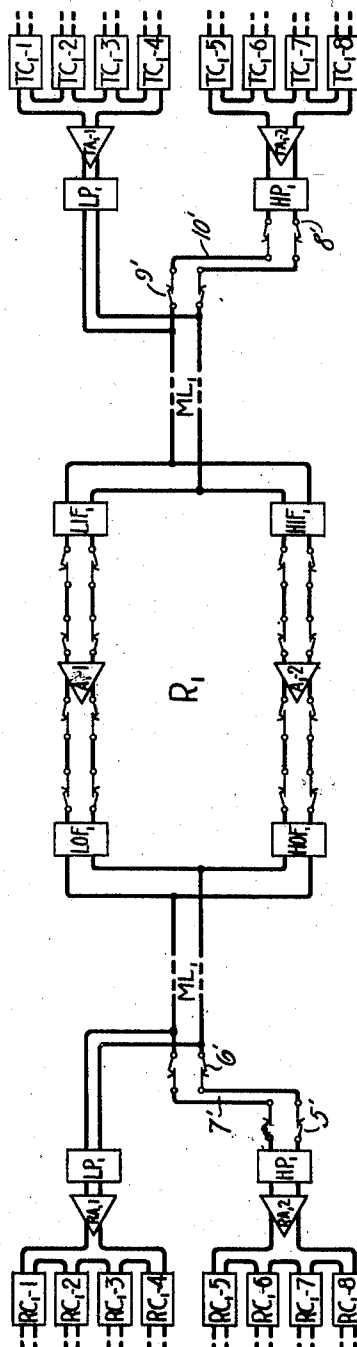


Fig. 1



STATION W

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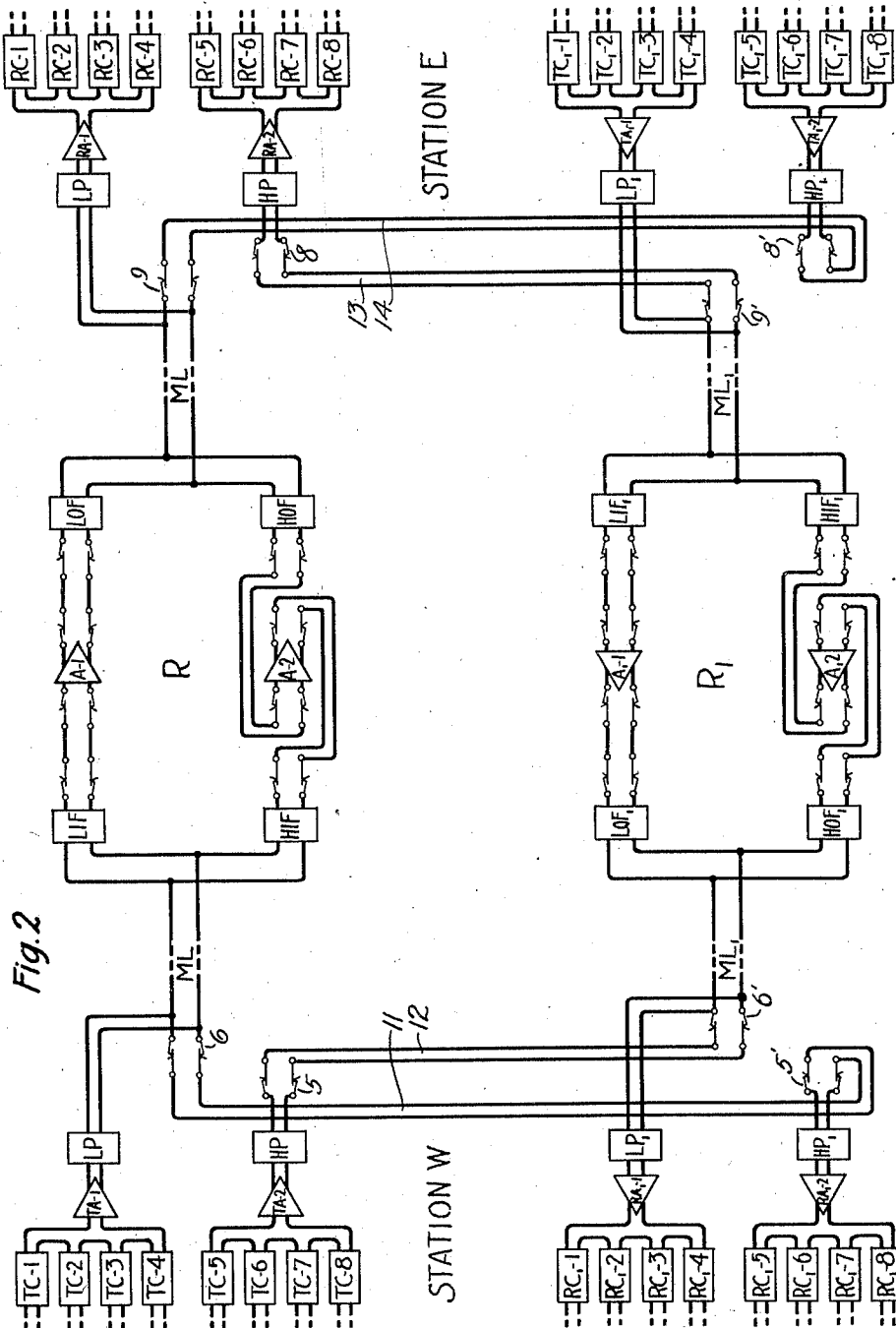
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MULTIPLEX SIGNALING SYSTEM

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3 Sheets-Sheet 2



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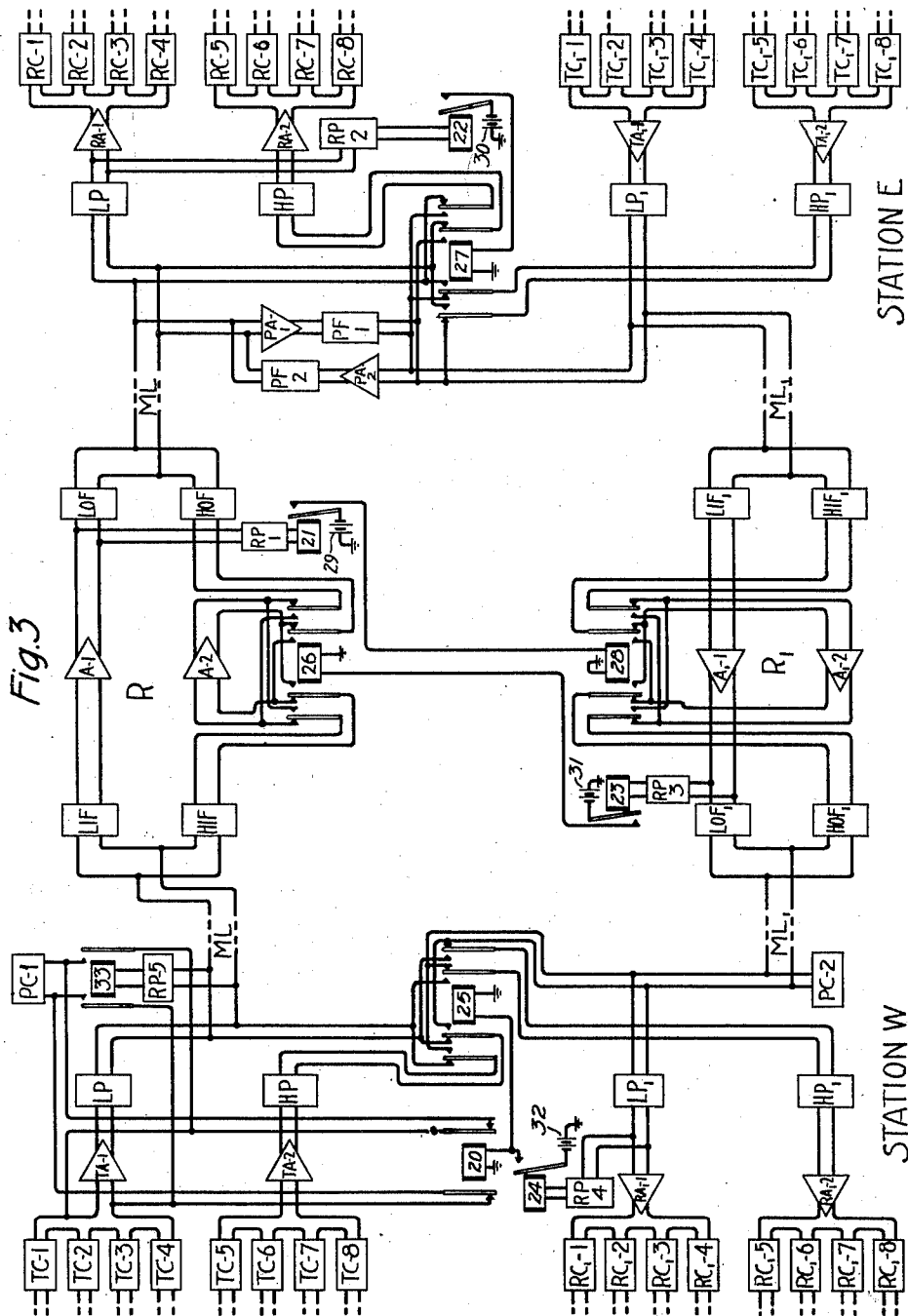
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MULTIPLEX SIGNALING SYSTEM

Filed Sept. 24, 1924

3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE.

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MULTIPLEX SIGNALING SYSTEM.

Application filed September 24, 1924. Serial No. 739,524.

This invention relates to multiplex signaling systems employing a plurality of currents or waves of different frequencies for the transmission of signals or for similar purposes.

An object of the invention is to improve the efficiency and to reduce the installation and maintenance costs of a multi-channel carrier current signaling system.

A related object of the invention is to reduce the number of signaling channels which may be lost to service due to the failure of the transmission medium of a carrier system.

The invention comprises a system in which multiplex transmission is applied to a circuit of the four-wire type, that is a circuit in which one transmission line is used for transmission in one direction and another transmission line is used for transmission in the opposite direction.

Under certain conditions systems of this type are much more efficient than two-wire carrier systems. For example, when two systems comprising a total of say eight signaling channels are operated on a two-wire basis on adjacent lines serious inter-system crosstalk results unless the lines are specially transposed at considerable expense. But when these eight channels are operated on a physical four-wire basis in the manner hereinafter described no line transposition is required other than that necessary to prevent singing at repeater points.

Heretofore, every four-wire system has been open to the objection that in case one pair of line conductors should fail the entire system would be put out of service, since it would be useless to carry on a one-way conversation over the line still in service, thus interrupting twice as many carrier channels as in the case of two-wire operation.

This difficulty is overcome in this invention by providing means for manually or automatically converting a four-wire system into two two-wire systems in case one of the transmission lines of the four-wire system should fail. In this way half of the transmitting and receiving channels may be operated as a two-wire system over the line that is still intact so that only half of the channels are lost to service.

The circuit for manually converting the four-wire system is so arranged that the switching operations may be performed by an ordinary plug and jack without rear-

ranging the carrier terminals or repeater apparatus in any way. A particular advantage of this system is that it may readily be applied to standard carrier signaling systems without otherwise altering the systems.

In the carrier system embodying the feature of automatic control a pilot current is transmitted continuously over both transmission lines. Switching circuits are controlled by the pilot current for automatically converting the four-wire system into two two-wire systems whenever either transmission line goes out of service. As long as either transmission line is out of service the entire system is, in effect, set up to operate as two two-wire systems one of which, of course, is useless since its transmission line is disrupted, and the other of which functions in a usual way for transmission in both directions. When the disrupted line is cut back in service the system is automatically returned to its original condition to function on a four-wire basis. This control is entirely automatic and requires no maintenance.

The invention will be described as applied to a multiplex carrier current telephone system, although it will be understood that it may also be applied to other signaling systems.

In the drawings:

Fig. 1 is a diagrammatic illustration of a four-wire carrier current telephone system constructed in accordance with the invention.

Fig. 2 is a diagrammatic illustration showing the system of Fig. 1 converted into two two-wire systems by means of manually operated switching devices.

Fig. 3 is a diagrammatic illustration of a four-wire carrier current telephone system embodying the automatic control feature of the invention.

The system of Fig. 1 is represented as comprising two terminal stations, W and E, respectively, interconnected by multiplex transmission line ML and ML₁.

One or more repeater stations R may be connected to the line ML intermediate the terminal stations, similar repeater stations R₁ being connected to the line ML₁ as required.

Transmission lines ML and ML₁, each comprise one pair of wires of a four-wire system which is utilized for the transmission of carrier currents between the two terminals. The line ML is used for transmis-

sion from station W to station E, while the line ML_1 is used for transmission from station E to station W.

A plurality of transmitting channels TC—1, TC—2, TC—3 etc., at station W are arranged for simultaneous and independent communication over the line ML with cooperating receiving channels RC—1, RC—2, RC—3, etc., at station E. While eight one-way channels are shown associated with the line ML it will be obvious that the number may vary as required.

The transmitting channels TC—1, TC—2, TC—3, etc., comprise the usual oscillator, modulator and transmitting band filter, while the receiving channels RC—1, RC—2, RC—3 etc., comprise the usual receiving band filter, demodulator and amplifier. Transmitting and receiving channels of this type are illustrated in Fig. 42 of a paper entitled "Carrier telephony and telegraphy" by Messrs. Colpitts and Blackwell, published in the Transactions of the American Institute of Electrical Engineers, volume 40, 1921.

Low pass grouping filters LP are paired with high pass grouping filters HP at each of the terminal stations for the purpose of separating the transmitting and receiving channels into upper and lower frequency groups. These filters and each of the other filters shown throughout the system may be constructed in accordance with the principles set forth in the United States patent to Campbell No. 1,227,113, issued May 22, 1917. Filters LP and HP at station W thus separate the lower group of transmitting channels TC—1 to TC—4 from the upper group of transmitting channels TC—5 to TC—8 while filters LP and HP at station E separate the lower group of receiving channels RC—1 to RC—4 from the upper group of receiving channels RC—5 to RC—8.

Transmitting amplifiers TA—1 and TA—2 are inserted between the grouping filters LP and HP and the lower and upper groups of transmitting channels, respectively, at station W. Similar receiving amplifiers RA—1 and RA—2 are employed at station E between the respective grouping filters and the lower and upper groups of receiving channels. These amplifiers may be of the well known unilateral thermionic electron discharge type.

The repeater R may be of any well known type such as that disclosed in the United States patent to Raibourn, No. 1,413,357, issued April 18, 1922. Separate repeater channels are provided for the upper and lower groups of frequencies transmitted in the same direction, thus reducing the load on the repeater amplifiers and consequently the likelihood of distortion. This provision also permits one of the repeater channels to

be utilized for transmission in the opposite direction as is hereinafter more fully explained. The channel for repeating the lower group of frequencies includes a low pass input filter LIF, a unilateral amplifier A—1 and a low pass output filter LOF, while the channel for repeating the upper group of frequencies includes a high pass input filter HIF, a unilateral amplifier A—2 and a high pass output filter HOF.

As is customary in telephone practice, the line ML terminates at stations W and E in jacks to which the respective groups of transmitting and receiving channels are connected by means of patching cords. At station W, for example, the upper group of transmitting channels terminating in jack 5 is connected to the line jack 6 by means of the cord 7, while the upper group of receiving channels terminating in jack 8 at station E is connected to the line jack 9 by means of cord 10. In practice, the lower group of transmitting and receiving channels are also connected to the line ML by means of similar plug and jack connections which, however, have been omitted from the drawing for the sake of clearness. A similar method of connecting the various circuit elements together is employed at the repeater R.

The various elements of the transmission lines ML and ML_1 , which together comprises the four-wire system, are identical, and hence a description of the line ML_1 is thought unnecessary. The elements associated with the line ML_1 are, designated by reference characters similar to those applied to the line ML, but with primes or subscripts affixed thereto. The direction of transmission of this line is, however, reversed, the transmitting channels of line ML_1 being located at station E and the receiving channels being located at station W.

Each of the transmitting channels of the line ML is associated at station W with a receiving channel of the line ML_1 through the usual hybrid coil circuits, not shown, to form groups of two-way communication channels. Each transmitting channel of the lower group is preferably associated with a receiving channel of the lower group. Thus, channel TC—1 and RC₁—1, TC—2, RC₁—2, TC—3 and RC₁—3 and so on, are connected respectively as pairs to low frequency signaling lines which may lead to switchboards or to ordinary subscribers' telephone stations. A similar arrangement is employed at station E.

A transmission system employing terminal circuits of this type is disclosed in the United States patent to Espenschied, No. 1,500,552, issued July 8, 1924. The low frequency lines may be associated with channels TC—1 and RC₁—1, TC—2 and RC₁—1, TC—3 and

RC_1-3 , $TC-5$ and RC_1-5 , etc., in the same manner in which low frequency lines L_1 , L_2 , etc., are associated with individual transmitting and receiving channels in Fig. 1 of the Espenschied patent. In this way a two-way conversation may be carried on between subscribers at station W and station E, a subscriber at station W talking, for example, over a circuit which includes channel $TC-1$, line ML and channel $RC-1$, and the subscriber at station E talking over a circuit which includes channel TC_1-1 , line ML_1 and channel RC_1-1 . In all, eight two-way conversations may be carried on simultaneously and independently over the system.

It is well that in transmission circuits, such as telephone circuits, where the lines parallel each other, or by reason of being carried along the same pole line or by reason of being included in the same cable, the telephonic or other signals transmitted over one line will induce corresponding currents in adjacent lines, thereby producing what is known as "crosstalk." This has led to the introduction in telephone circuits of what are known as line transpositions at certain intervals for the purpose of balancing out the induced crosstalk currents.

In the case of multiplex carrier current telephone systems the problem of reducing crosstalk becomes one of much greater magnitude than in the case of ordinary telephonic transmission. This follows because the currents induced are greater in the case of the higher frequencies involved, and because the accurate spacing of the transpositions and of the line wires is much more important due to the large number of transpositions required.

In attempting to reduce crosstalk between carrier current channels of adjacent lines by means of line transpositions, it is necessary that a large number of transpositions occur per wave length of the highest frequency involved. To effectively transpose the transmission lines involves considerable expense in the case of a carrier transmission circuit in which the wave lengths employed are very much shorter than those employed in ordinary telephone practice, since the transpositions must occur at frequent intervals.

To overcome this difficulty the same group of frequencies are employed for transmission in opposite directions in the four-wire system of this invention. In other words, the respective carrier frequencies employed by the transmitting channels $TC-1$, $TC-2$, $TC-3$, etc., at station W are identical with those employed by transmitting channels TC_1-1 , TC_1-2 , TC_1-3 , etc., at station E. If, under these conditions, a voice-modulated wave of 5000 cycles frequency is transmitted over the line ML from transmitting channel $TC-1$, a corresponding current which might be induced in the line ML_1 would not produce

interference in the transmitting channels associated with line ML_1 at station E, since the one-way terminal amplifiers would not pass currents transmitted in that direction. At station W the current induced in line ML_1 would be effectively prevented from entering all of the receiving channels except channel RC_1-1 by the high pass filter HIP_1 and the band filters associated with the respective lower group of receiving channels. Such a current would, therefore, only be passed through receiving channel RC_1-1 , from which it would be transmitted to the low frequency line and appear as near-end crosstalk, that is, as side-tone, in the talker's own receiver, which, of course, would have no effect whatever upon the conversation.

By thus operating all of the channels on a physical four-wire basis, using the same group of frequencies in each direction, no line transportation is required other than that which may be necessary to prevent singing at repeater points.

As pointed out above four-wire carrier current systems have heretofore been open to the objection that in case one of the transmission lines should fail the entire system would be put out of service. If the line ML should be disrupted for example, the line ML_1 would likewise be rendered useless under the old method of operation since there would be no way of transmitting messages from station W to station E.

This difficulty is overcome in accordance with the invention by a simple switching arrangement at the terminal and repeater stations whereby the system may still function as a two-way system over the line that is still in service. This feature of the invention will appear more clearly from the consideration of Fig. 2.

When trouble occurs on either of the transmission lines ML or ML_1 the attendants at the terminal stations may not know at once which line is affected, and hence in practice it is preferable to set the four-wire system up as two two-wire systems, rather than to prepare only one line to operate on a two-wire basis. This is accomplished by simply disconnecting one group of transmitting and receiving channels at each terminal station from their respective transmission lines and connecting them to the other transmission line. The corresponding repeater channel is also reversed by a similar manual switching operation.

Assuming that one of the transmission lines, which may be the line ML , has been disrupted, and it is desired to utilize the line ML_1 as a two-way transmission circuit until the line ML has been repaired, the attendant at station W will remove patching cords 7 and 7' and the attendant at station E will remove cords 10 and 10' shown in Fig. 1. The line ML is then connected with the up-

per group of receiving channels at station W by means of patching cord 11 having plugs on either end which cooperate with line jack 6 and station jack 5'. The upper group of transmitting channels at station W are connected to the line ML_1 by means of the cord 12, the connecting plugs of which cooperate with station jack 5 and line jack 6'. At station E a similar switching operation is made by connecting cord 13 between station jack 8 and line jack 9' to connect the upper group of receiving channels to the line ML_1 and by plugging the patching cord 14 into station jack 8' and line jack 9 to connect the upper group of transmitting channels to the line ML_1 .

Since in each case the terminal connections of the upper group of transmitting and receiving channels have been reversed, the direction of the upper repeating channel at repeaters R and R_1 must also be reversed if waves are to be transmitted through either repeater in both directions. The patching cord connecting filters HIF and HOF to the input and output, respectively, of amplifier A-2, shown in Fig. 1, are therefore removed and by means of the same or similar cords filter HIF is connected to the output of amplifier A-2 and filter HOF is connected to the input of amplifier A-2. A similar change is made in the circuit connecting filters HIF₁ and HOF₁ to amplifier A₁-2 of repeater R₁, as shown in Fig. 2.

The arrangement of the low frequency lines at the terminal stations must also be changed to correspond to the rearranged high frequency circuits. Any suitable switching means, such as plugs and jacks, may be employed for this purpose. When the high frequency circuits has been reversed in the manner described above, transmitting channel TC-5 and receiving channel RC₁-1 at station W are connected as a pair to a common low frequency line. Channels TC-6 and RC₁-2, TC-7 and RC₁-3 and so on are also connected as pairs to low frequency lines. At station E channels RC-5 and TC₁-1, and so on are similarly connected in pairs to the low frequency lines. For the sake of clearness, however, the low frequency switching plugs and jacks are omitted in the drawing.

When the circuit is set up as shown in Fig. 2, the line ML_1 being out of service, the upper group of transmitting channels at station W cooperate with the upper group of receiving channels at station E and the lower group of transmitting channels at station E cooperate with the lower group of receiving channels at station W to form a two-way carrier current telephone system employing the line ML_1 as a transmission medium. Voice-modulated waves originating in channel TC-5, for example, are transmitted through transmitting amplifiers

TA-2, high pass grouping filter HP, jack 5, cord 12, jack 6', line ML_1 , repeater filter HOF₁, amplifier A₁-2, the direction of which has been reversed, filter HIF, line ML_1 , jack 9', cord 13, jack 8, high pass grouping filter HP, receiving amplifier RA-2, receiving channel RC-5, wherein the received wave is demodulated and the voice frequency component is passed to the associated low frequency line in the usual manner. For transmission from station E to station W, a voice-modulated wave originating for example in channel TC₁-1, is transmitted through transmitting amplifier TA₁-1, low pass filter LP₁, line ML_1 , repeater filter LIF₁, amplifier A₁-1, filter LOF₁, line ML_1 , low pass filter LP₁, receiving amplifier RA₁-1, receiving channel RC₁-1, wherein the received wave is demodulated and the voice frequency component is passed to the associated low frequency line in the usual manner.

If, on the other hand, the line ML_1 is disrupted and only the line ML remains in service, then the lower group of transmitting channels at station W cooperates with the lower group of receiving channels at station E and the upper group of transmitting channels at station E cooperates with the other group of receiving channels at station W to form a two-way transmission system, utilizing the single transmission line ML . In this case, the higher group of frequencies transmitted from station E to station W are transmitted through amplifier A-2 of repeater R, the direction of which has been reversed in the manner described, while the lower group of frequencies transmitted from station W to station E are transmitted through repeater amplifier A-1 the direction of which is unchanged.

When the transmission line which has been rendered inoperative is again cut back in service the system may be restored to its original condition by the simple manual operation of adjusting the terminal and repeater patching cords. In this way the system may be switched over from a four-wire circuit to operate half of the total number of channels on a two-wire basis with a minimum delay and maximum efficiency whenever occasion demands.

Fig. 3 shows a modification of the invention in which a pilot current is utilized to automatically convert a four-wire system into two two-wire systems upon the failure of either pair of line wires.

Since carrier current telephone systems usually provide for pilot channels for regulating the transmission line, the system of automatic control hereinafter described may readily be applied to carrier systems already in existence without otherwise changing the terminal or repeater circuits thereof.

In accordance with the invention, a pilot

current of distinctive frequency is impressed upon one pair of transmission wires at one terminal station along with the signal currents for transmission to the remote terminal station. At the remote station the received pilot current is impressed upon the second pair of transmission wires for transmission back to the first station.

Switching circuits under the control of the pilot current are provided at the terminal stations, as well as at intermediate repeater points, for automatically converting the four-wire system into two two-wire systems and for cutting off the transmission of the pilot current if either pair of line wires should fail. As soon as the disrupted line has been repaired and cut back in service, a second pilot current of distinctive frequency is transmitted over a circuit including both pairs of line wires and serves to operate mechanisms for again impressing the original pilot current upon the transmission lines. The original pilot current, when transmitted over the circuit, serves to operate switching mechanisms to return the system to its normal four-wire operation.

In addition to the signaling channels indicated in Fig. 3, which are identical to those shown in Figs. 1 and 2, a pilot channel PC—1 is also associated with the line ML at station W at a point intermediate the lower group of transmitting channels and the transmitting amplifier TA—1. The pilot channel PC—1 includes the usual transmitting oscillator, amplifier and band filter. The pilot oscillator is adapted to continuously supply a pilot current of a frequency different from that of any of the signaling channels, but which is nevertheless within the transmission range of the low pass terminal filters LP and the low pass repeater filters.

In operation, the pilot current originating in the pilot channel PC—1 is transmitted through the left and right hand contacts of relay 20, transmitting amplifier TA—1, low pass filter LP, transmission line ML to the repeater R. At the repeater the pilot current is transmitted through low pass input filter LIF to the amplifier A—1 and then divides, a portion of the current being transmitted through low pass output filter LOF to the line ML and a portion of the current being transmitted through the pilot receiving circuit RP—1. The pilot receiving circuit RP—1 comprises a band filter adapted to selectively transmit the pilot current, and an amplifier-rectifier which may be of the well known thermionic electron discharge type. The pilot current transmitted through this circuit is rectified and caused to operate a relay 21 in the output thereof for a purpose hereinafter to be described. The pilot current received at station E from line ML again divides, a portion being trans-

mitted over line ML₁ back to the station W and a portion being transmitted through low pass filter LP to the pilot receiving circuit RP—2. The current transmitted through pilot receiving circuit RP—2, which is identical to receiving circuit RP—1, is rectified and caused to maintain the relay 22 energized, as shown. The portion of the pilot current which is retransmitted to station W is amplified in the amplifier PA—1 and is selectively transmitted through filter PF—1 to the line ML₁. At repeater R₁ the pilot current is transmitted through low pass input filter LIF₁, amplifier A₁—1 and thereupon divides, a portion of the current being transmitted through the low pass output filter LOF₁ to the line ML₁ and a portion being transmitted to the receiving pilot circuit RP—3, which is identical to the pilot receiving circuits RP—1 and RP—2. The relay 23 is maintained energized by the rectified current in the output of pilot receiving circuit RP—3. The pilot current received from the line ML₁ at station W is transmitted through low pass filter LP₁ and is selectively transmitted by the pilot receiving circuit RP—4, where it is rectified and caused to energize the relay 24.

It will thus be seen that when the transmission lines ML and ML₁ are both in service the pilot current originating in the pilot channel PC—1 is continuously transmitted over both these lines, and during such transmission is caused to maintain relays 21, 22, 23 and 24 energized in the manner shown.

The system when in this condition functions as a four-wire system, the transmission line ML being utilized for transmission from station W to station E and the transmission line ML₁ being utilized for transmission from station E to station W.

Therefore, voice-modulated waves originating in one of the lower group of transmitting channels at station W, for example in transmitting channel TC—1, are transmitted through transmitting amplifier TA—1, low pass filter LP, line ML, low pass repeater input filter LIF, amplifier A—1, low pass repeater output filter LOF, line ML, low pass filter LP at station E, receiving amplifier RA—1 to receiving channel RC—1, where the received waves are demodulated and the voice frequency components are passed to the associated low frequency telephone line in the usual manner. Voice-modulated waves originating in one of the upper groups of transmitting channels at station W, for example in channel TC—5, are transmitted through transmitting amplifier TA—2, high pass filter HP, armatures and left hand front contacts of relay 25, transmission line ML, high pass input repeater filter HIF, left hand armatures and back contacts of relay 25, line ML, high pass repeater input filter HIF, right hand back

contacts and armatures of relay 26, amplifier A—2, high pass repeater output filter HOF, line ML, right hand back contacts and armatures of relay 27, high pass filter HP, receiving amplifier RA—2 to receiving channel RC—5, where the received waves are demodulated and the voice frequency components are passed to the associated low frequency telephone line.

The transmissions from station E to station W are accomplished in a similar manner. Voice-modulated waves originating in one of the lower group of transmitting channels at station E, for example in channel TC₁—1, are transmitted through transmitting amplifier TA₁—1, low pass grouping filter LP₁, line ML₁, low pass repeater input filter LIF₁, amplifier A₁—1, low pass repeater output filter LOF₁, line ML₁, low pass grouping filter LP₁, receiving amplifier RA₁—1, receiving channel RC₁—1 whence the demodulated waves are transmitted to the associated low frequency telephone line. Voice modulated waves originating in one of the upper group of transmitting channels at station E, for example in channel TC₁—5, are transmitted through transmitting amplifier TA₁—2, high pass grouping filter HP₁, left hand armatures and back contacts of relay 27, line ML₁, high pass repeater input filter HIF₁, right hand armatures and back contacts of relay 28, amplifier A₁—2, left hand back contacts and armatures of relay 28, high pass repeater output filter HOF₁, line ML₁, right hand back contacts and armatures of relay 25, high pass grouping filter HP₁, receiving amplifier RA₁—2 to receiving channel RC₁—5, whence the demodulated waves are transmitted to the associated low frequency telephone line.

If, during the operation of the four-wire system as described above, either of the transmission lines ML or ML₁ should be disrupted or otherwise lost to service, the pilot circuit will function to automatically convert the remaining transmission line into a two-way path for the transmission of signals in both directions between terminal stations.

Assume, for example, that the transmission line ML has been disrupted at a point between station W and repeater R, thereby preventing the transmission of signals over this line. In this case, the pilot current originating in channel PC—1 is cut off from transmission to the pilot receiving circuits RP—1, RP—2, RP—3 and RP—4. Since rectified current no longer flows in the output of these pilot receiving circuits the relays 21, 22, 23 and 24 are deenergized.

Relay 21 in releasing its armature establishes an operating circuit for relay 23, which extends from ground through battery 29, armature and contact of relay 21, winding of

relay 28 to ground. Relay 22 in releasing its armature establishes an operating circuit for relay 27 which extends from ground, through battery 30, armature and contact of relay 22, winding of relay 27 to ground. Similarly, the deenergization of relay 23 causes the operation of relay 26 over a circuit extending from ground through battery 31, armature and contact of relay 23, winding of relay 26 to ground. Relay 24 in releasing its armature establishes an operating circuit for relay 25, which may be traced from ground through battery 32, armature and contact of relay 24, winding of relay 25 to ground, and also operates relay 20 over a circuit extending from ground through battery 32, armature and contact of relay 24, winding of relay 20 to ground.

The energization of relays 25, 26, 27 and 28 accomplished in the manner described above causes each of these relays to attract both left and right hand windings, in each case opening the back contacts of these relays which are shown closed in the drawing and closing the respective front contacts thereof. The operation of relay 25 disconnects the upper group of transmitting channels, TC—5, etc., at station W from the disrupted line ML and connects these channels to the line ML₁, and at the same time disconnects the upper group of receiving channels RC₁—5, etc., from line ML₁ and connects these channels to the line ML. The lower group of transmitting and receiving channels at station W are unaffected by this switching operation. At station W, therefore, the lower group of receiving channels RC₁—1, etc., and the upper group of transmitting channels TC—5, etc., are associated with the line ML₁ which is still in service. The operation of relay 27 at station E disconnects the upper group of receiving channels RC—5, etc., from the disrupted line ML and connects these channels to the line ML₁, and at the same time disconnects the upper group of transmitting channels TC₁—5, etc., from line ML₁ and connects these channels to line ML. The lower group of transmitting and receiving channels at station E are not affected by this switching operation. Accordingly, the upper group of receiving channels RC—5, etc., and the lower group of transmitting channels TC₁—1, etc., are now connected in the transmission line ML₁ and are adapted to cooperate with the upper group of transmitting channels and the lower group of receiving channels at station W for the two-way transmission of signals over line ML₁.

The operation of relay 28 at repeater R serves to reverse the direction of repeater amplifier A₁—2, whereby the upper group of frequencies transmitted from station W may be transmitted through amplifier A₁—2 to station E. The operation of relay 26 at

repeater R reverses the repeater amplifier A—2.

The energization of relay 20 at station W causes this relay to attract its armatures to disconnect the pilot channel PC—1 from line ML.

When the system has thus been set up to function as a two-wire system using the line ML₁ as a two-way transmission path, voice modulated waves originating in the lower group of transmitting channels TC₁—1 etc., at station E are transmitted over the line ML₁ and repeater R₁ to station W, where they are received in the lower group of receiving channel RC₁—1, etc., in the identical manner described above. For transmission over the line ML₁ from station W to station E, however, the upper group of frequencies are utilized. Voice-modulated waves originating, for example, in transmitting channel TC—5 at station W are transmitted through transmitting amplifier TA—2, high pass grouping filter HP, left hand armatures and front contacts of relay 25, line ML₁, high pass repeater filter HOF₁, left hand armatures and front contacts of relay 28, amplifier A₁—2, right hand front contacts and armatures of relay 28, high pass repeater filter HIF₁, line ML₁, right hand front contacts and armatures of relay 27 at station E, high pass grouping filter HP, receiving amplifier RA—2, to receiving channel RC—5, whence the demodulated waves are transmitted to the associated low frequency telephone line.

If the break in the transmission line ML instead of occurring at a point intermediate station W and repeater R had occurred between repeater R and station E the operation of the switching circuits would nevertheless be the same as that described above. In this case, although the pilot current originating in pilot channel PC—1 would momentarily be transmitted to the pilot receiving circuit RP₁, thus maintaining relay 21 energized, nevertheless since the pilot current is cut off from pilot receiving circuit RP—4 and relay 24 is accordingly deenergized the relay 20 is immediately operated to disconnect the pilot channel PC—1 from the line ML, whereupon the relay 21 at repeater R is deenergized thus causing the operation of relay 28 at repeater R₁.

When the line ML has been prepared and is cut back in service the system is automatically returned to its original condition to function as a four-wire system. This is accomplished in the following manner:

A pilot channel PC—2 is connected to line ML₁ at station W and is adapted to furnish a pilot current of distinctive frequency within the range transmitted by the upper group of filters such as filter HOF₁. The pilot oscillator associated with pilot channel PC—2 may be operated continuously, but

the pilot current generated thereby is normally suppressed from transmission over the line ML₁ due to the fact that when the system is operated on a four-wire basis this pilot current cannot be transmitted through the unilateral amplifier A₁—2 of repeater R₁. However, as soon as the system is converted to operate on a two-wire basis as described above the pilot current from channel PC—2 will readily be transmitted through repeater amplifier A₁—2. Therefore when the disrupted line ML is cut back in service the pilot current from channel PC—2 is transmitted through line ML₁, high pass repeater filter HOF₁, left hand armatures and front contacts of relay 28, amplifier A₁—2, right hand front contacts and armatures of relay 28, high pass repeater filter HIF₁, line ML₁, pilot amplifier PA—2, pilot filter PF—2, line ML, high pass repeater filter HOF, right hand armatures and front contacts of relay 26 since relay 26 is energized, amplifier A—2, left hand front contacts and armatures of relay 26, high pass repeater filter HIF, line ML to the pilot receiving circuit RP—5. The pilot receiving circuit RP—5 is similar in construction to pilot receiving circuits RP—1, RP—2 etc., and the rectified currents in the output of this circuit are caused to operate pilot relay 33. The operation of relay 33 serves to connect pilot channel PC—1 to the common transmitting circuit intermediate the lower group of transmitting channels TC—1, etc., and transmitting amplifier TA—1. The pilot current from channel PC—1 is thus again transmitted over lines ML and ML₁ to the pilot receiving circuits RP—1, RP—2, RP—3, and RP—4. The rectified pilot current in the output of these pilot receiving circuits again energizes relays 21, 22, 23 and 24 to restore the system to the original condition shown in the drawing.

The pilot current from channel PC—2 is thus cut off from transmission since it cannot pass through the unilateral amplifier A₁—2 of repeater R₁ and relay 33 in the output of the pilot receiving circuit RP—5 is deenergized. However, relay 24 at station W in attracting its armature deenergizes relay 20, the armatures of which, in turn, fall back and establish a circuit from pilot channel PC—1 to the line ML. The pilot current in channel PC—1 is thus again continuously transmitted over the system and is adapted to cause the switching operations described above should either of the lines ML or ML₁ be again cut out of service.

When the system is converted automatically in the manner described above, the low frequency lines at the terminal stations may also be shifted to correspond to the altered condition of the high frequency circuits. The reversing mechanisms for the low frequency circuits may be controlled by the

pilot circuits in the same manner as that described in connection with the high frequency circuits.

When the line ML_1 is disrupted while line ML remains in service the system is set up to operate on a two-wire basis in the same manner as that described above except that in such case the transmissions are carried on in both directions over the line ML .

The invention set forth herein is, of course, susceptible of various modifications and adaptations, and accordingly the invention is not to be considered as limited to the particular disclosure.

What is claimed is:

1. A multiplex signaling system comprising two terminals, a pair of transmission lines and a repeating station for connecting said terminals, means at each of said terminals for transmitting signals in one direction only over one of said lines and for receiving signals in the opposite direction only over the other of said lines; switching means at each of said terminals for interchanging a portion of said transmitting and receiving means and switching means for interchanging a portion of the apparatus at said repeating station whereby signals may be transmitted in both directions over at least one of said lines.

2. A multiplex signaling system comprising two terminals, a pair of transmission lines connecting said terminals, means at each of said terminals for transmitting waves in two groups of frequencies respectively comprising in two different frequency ranges over one of said lines and for receiving waves in two groups of frequencies respectively comprised in said two frequency ranges over the other of said lines, and switching means at each of said terminals for connecting the receiving means of one of said frequency groups with the transmitting line and for connecting the transmitting means of one of said frequency groups with the receiving line thereat, whereby signals at each station may be transmitted in one direction by waves within one of said frequency ranges and received by waves within the other of said frequency ranges over one of said lines when the other line is disrupted.

3. A multiplex signaling system comprising two terminals, a pair of transmission lines connecting said terminals, two groups of transmitting and receiving channels at each of said terminals for transmitting carrier waves within a high and a low frequency range in one direction over one of said lines and for receiving carrier waves within said high and said low frequency range in the opposite direction over the other of said lines; switching means at each of said terminals for connecting one of the groups of receiving channels to the trans-

mitting line thereat and switching means at each of said terminals for connecting one of the groups of transmitting channels to the receiving line thereat, whereby signals at each station may be transmitted in one direction by waves within one of said frequency ranges and received by waves within the other of said frequency ranges over one of said lines when the other line is disrupted.

4. A multiplex signaling system comprising two terminals, a pair of transmission lines connecting said terminals, two groups of transmitting and receiving channels at each of said terminals for transmitting carrier waves in one direction over one of said lines and for receiving carrier waves in the opposite direction over the other of said lines, a repeater comprising two channels connected to each of said lines at a point intermediate said terminals for amplifying the waves comprised in the respective groups in one direction, switching means at each of said terminals for connecting one of the groups of receiving channels to the transmitting line thereat, switching means at each of said terminals for connecting one of the groups of transmitting channels to the receiving line thereat, and switching means at each of said repeaters for reversing the direction of amplification on one of the repeater channels, whereby waves may be transmitted in both directions over one of said lines when the other line is lost to service.

5. A multiplex signaling system comprising a plurality of transmission lines, means for insuring the transmitting of signals in one direction only over each of said lines under normal operating conditions, and means for varying the connections of said lines automatically to transmit signals in the opposite direction over one of said lines when another of said lines is disrupted.

6. A multiplex signaling system comprising two terminals, a pair of transmission lines connecting said terminals, means at said terminals for insuring the transmitting of signals in one direction only over each of said lines, and automatic switching means operated under predetermined conditions for varying the connections of said lines to transmit signals in the other direction over one of said lines.

7. A multiplex signaling system comprising two terminals, a pair of transmission lines connecting said terminals, means at each of said terminals for transmitting waves comprised in two groups of frequencies over one of said lines and for receiving waves comprised in two groups of frequencies over the other of said lines, and automatic switching means operated under predetermined conditions for connecting the receiving means of one of said frequency groups with the transmitting line and for

connecting the transmitting means of one of said groups with the receiving line at each of said terminals.

8. A multiplex signaling system comprising two terminals, a pair of transmission lines connecting said terminals, means at said terminals for transmitting signals in one direction over each of said lines, means for transmitting a control current over said lines and switching means operated by said control current under predetermined conditions for transmitting signals in the other direction over one of said lines.

9. A multiplex signaling system comprising two terminals, a pair of transmission lines connecting said terminals, two groups of transmitting and receiving channels at each of said terminals for transmitting carrier waves in one direction over one of said lines and for receiving carrier waves in the opposite direction over the other of said lines, means for transmitting a control current over said lines, and switching means operated by said control current under predetermined conditions for connecting one of the groups of receiving channels to the transmitting line and for connecting one of the groups of transmitting channels to the receiving line thereat.

10. A multiplex signaling system comprising two terminals, a pair of transmission lines connecting said terminals, two groups of transmitting and receiving channels at each of said terminals for transmitting carrier waves in one direction over one of said lines and for receiving carrier waves in the opposite direction over the other of said lines, a repeater comprising two channels connected to each of said lines intermediate said terminals for amplifying the waves comprised in the respective groups in the one direction, means for transmitting a pilot current over a loop circuit including both of said transmission lines, switching means at each of said terminals operated by the failure of said pilot current to connect one of the groups of receiving channels to the transmitting line and to connect one of the groups of transmitting channels to the receiving line thereat, and switching means operated by the failure of said pilot current at each of said repeaters for reversing the direction of amplification of one of the repeater channels, whereby waves may be

transmitted in both directions over one of said lines when the other line is disrupted.

11. A multiplex signaling system comprising two terminals, a pair of transmission lines connecting said terminals, two groups of transmitting and receiving channels at each of said terminals for transmitting carrier waves in one direction over one of said lines and for receiving carrier waves in the opposite direction over the other of said lines, a repeater comprising two channels connected to each of said lines intermediate said terminals for amplifying the waves comprised in the respective groups in the one direction, means for transmitting a pilot current over a loop circuit including both of said transmission lines, switching means at each of said terminals operated by the failure of said pilot current to connect one of the groups of receiving channels to the transmitting line and to connect one of the groups of transmitting channels to the receiving line thereat and also to disconnect said pilot transmitting means from said loop circuit, switching means operated by the failure of said pilot current at each of said repeaters for reversing the direction of amplification of one of the repeater channels, whereby waves may be transmitted in both directions over one of said lines when the other line is disrupted, means controlled by said terminal and repeater switching means for transmitting a second pilot current over said transmission lines under predetermined conditions, and switching means controlled by said second pilot current for again impressing said first pilot current upon said transmission lines.

12. In a carrier signaling system, a pair of one-way lines, carrier transmitting and carrier receiving sets, means for connecting said sets to said one-way lines to form a four-wire two-way system using the same carrier frequencies for transmission in both directions and means for altering the connections of certain of said sets to said lines to convert either line into a two-way carrier signaling line employing different carrier frequencies for transmission in opposite directions.

In witness whereof, I hereunto subscribe my name this 18th day of September, A. D., 1924.

JACOB S. JAMMER.