Oct. 29, 1935. F. A. LEIBE 2,018,859

UNATTENDED REPEATER SYSTEM

Filed June 9, 1934 2 Sheets-Sheet 1

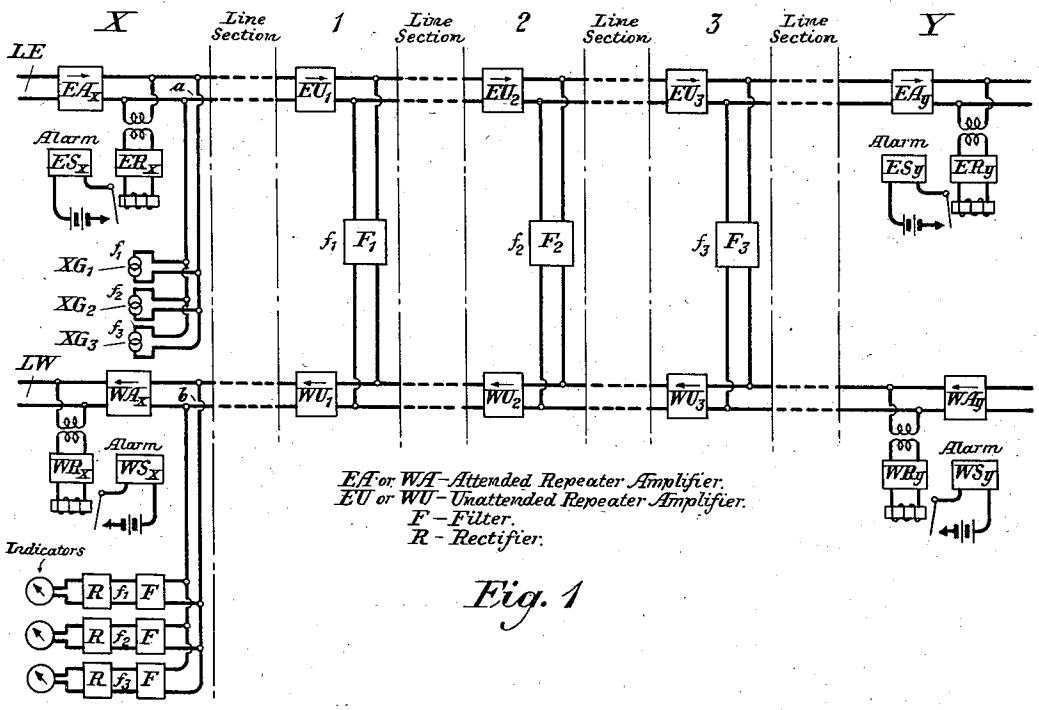


Fig. 1

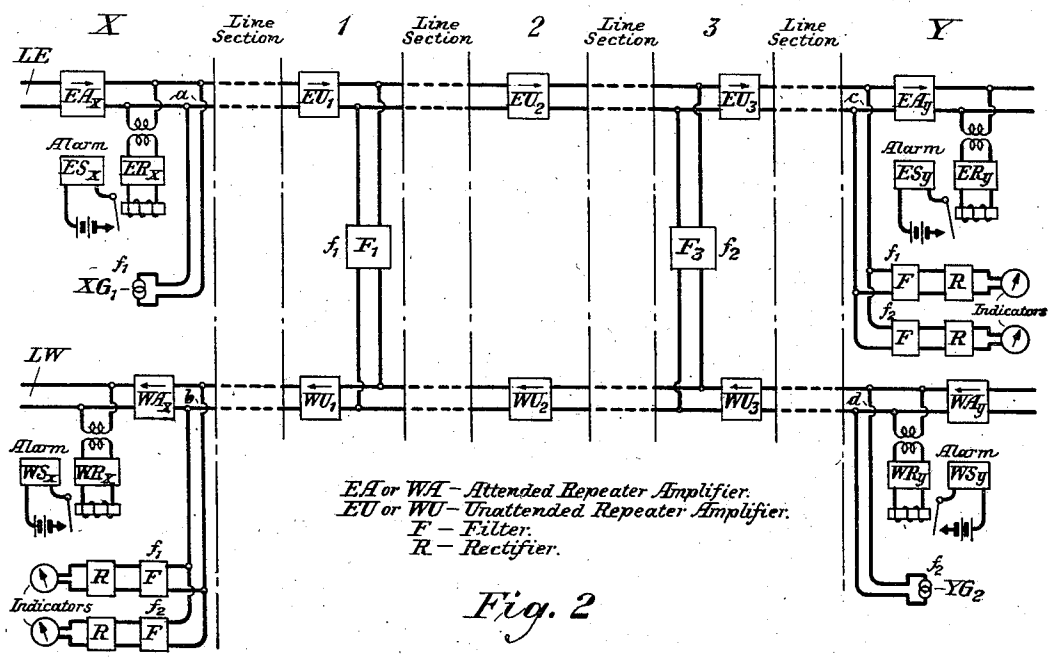


Fig. 2

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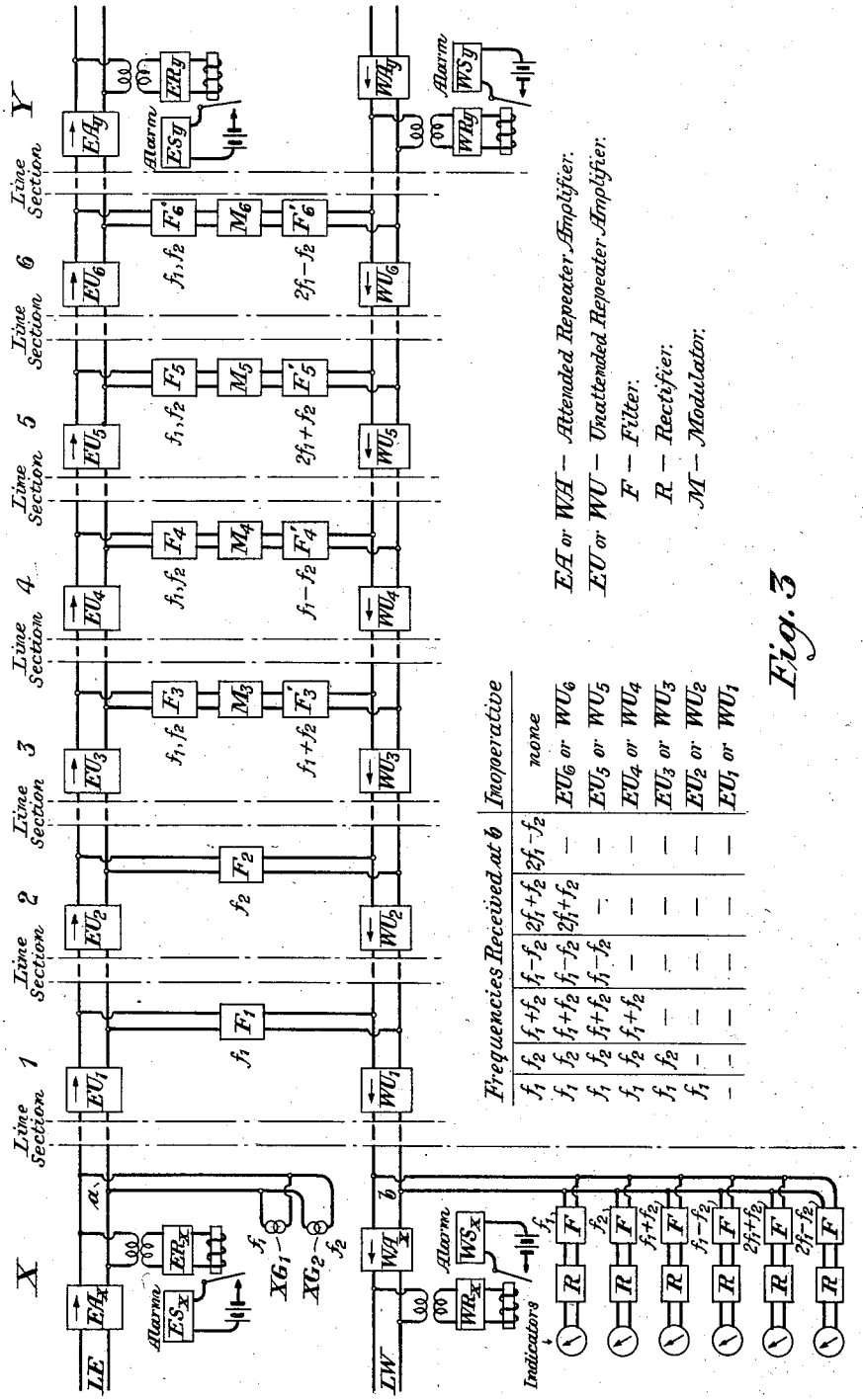


Fig. 3

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2,018,859

UNITED STATES PATENT OFFICE

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UNATTENDED REPEATER SYSTEM

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Application June 9, 1934, Serial No. 729,921

10 Claims. (Cl. 177—311)

This invention relates to transmission systems and more particularly to systems involving unattended repeater stations.

In the development of new types of transmission systems, particularly those employing wide ranges of frequencies, it is desirable to employ repeaters spaced at more frequent intervals. Because of the large number of repeaters involved, it is desirable that some of the repeaters be left unattended especially as repeaters have been developed which are sufficiently reliable in performance to be left unattended in suitable housings for considerable periods of time.

Regardless of the degree of reliability which is attained in the development of such unattended repeaters, however, the possibility of an occasional failure can never be entirely ruled out. Where more than one unattended repeater is employed between adjacent attended stations, it is desirable, in the event of failure of one of the unattended repeaters, to have available some means whereby the attendant at an attended repeater station may readily determine which unattended repeater is inoperative. It is one of the purposes of the present invention to provide facilities whereby this information may be obtained at attended repeater points.

The indication at the attended repeater point may be based upon the ability of the unattended repeater to amplify (*a*) the voice, television, or other signals transmitted; or (*b*) the indication may be based upon the ability of the amplifier to transmit a pilot frequency or frequencies.

In a system having so few communication channels superimposed on it that the signals passing through the unattended repeater will be intermittent in character, it would be preferable to base the indication upon a pilot frequency or frequencies which are continuously transmitted.

Various types of signaling systems for indicating failure of a repeater and for determining the location of the repeater which has failed, may be provided. For example, the system may be arranged to transmit continuously through the unattended repeaters an alternating current which may be either the normal signaling currents passing over the system or a special pilot frequency. Each unattended repeater may be so related to a direct current path common to all of the unattended repeaters of the group, that upon failure of the repeater to operate, a change will be produced in the condition of the direct current path thereby producing a signal at an attended repeater station. The attendant upon observing the signal may then test over the direct current path to determine the point at which the change in condition has occurred, as, for example, by making resistance measurements.

The invention may also be embodied in an arrangement in which, when the repeater fails, the location of the repeater may be indicated at an attended station directly, without the necessity of any testing operation. For example, instead of using a direct current path a plurality of pilot frequencies, one corresponding to each unattended repeater, may be transmitted over the circuit from the attended station through the various unattended stations. Each unattended station is arranged to exercise control over the pilot frequency assigned to that particular station, and upon the failure of a particular unattended repeater that repeater will be identified by the fact that the pilot frequency corresponding thereto produces no indication at the indicating point.

Also, the invention may be embodied in an arrangement in which, instead of transmitting separate pilot frequencies or other signaling currents for testing purposes over each one-way transmission circuit of a two-way system, as is contemplated in the arrangements above described, a combined indicating arrangement for both directions may be used. For example, failure of the unattended repeater for either direction at a given repeater station may be caused to produce at an attended repeater an indication of the station at which the failure has taken place. An additional signal individual to each directional path and common to all of the unattended repeaters in tandem in that path, may be used to indicate failure of any repeater in the path. By means of the two indications the individual repeater which has failed may be ascertained.

Only arrangements corresponding to the third type of system above mentioned, are disclosed herein. Systems of the first type are disclosed and claimed in the joint application of E. I. Green and F. A. Leibe, Serial No. 729,922 filed June 9, 1934. Systems of the second type above described, are disclosed and claimed in a joint application of E. I. Green and F. A. Leibe, Serial No. 729,923 filed June 9, 1934.

The invention will now be more fully understood from the following detailed description thereof when read in connection with the accompanying drawings in which Figures 1, 2 and 3 illustrate three embodiments of a system for indicating the location of an unattended repeater

that has failed in a two-way system employing a combined indicating arrangement for both directions of transmission.

Referring to Fig. 1, LE designates a portion of the transmission circuit transmitting from west to east between attended repeater stations X and Y, and LW designates the corresponding portion of the return circuit for transmitting from east to west. Each transmission path has unattended repeaters at stations 1, 2 and 3 intermediate between the attended repeater stations X and Y. An attended repeater EA_x is connected in line LE at station X, and associated with the output of said repeater through a suitable transformer is a rectifier ER_x. As long as transmission passes through the repeater EA_x the rectifier ER_x rectifies a portion of the received transmission and thereby energizes a relay. The received currents to be rectified may be either normal signaling currents or, as previously stated, where the number of channels normally transmitted is too small to assure that some signal will be transmitted at all times, a pilot frequency may be transmitted over the line LE to hold up the relay. If the repeater EA_x or any portion of the transmission circuit ahead of said repeater should fail, there will be no current in the output of the rectifier ER_x and the relay will be released to actuate the alarm signal ES_x. At station Y a similar rectifier ER_y is associated through a transformer with the output of an attended repeater EA_y and controls through its relay an alarm signal ES_y. The operation of the alarm ES_y will indicate failure of the repeater EA_y, or failure in the circuit ahead of the repeater EA_y. At stations 1, 2 and 3 unattended repeaters EU_1, EU_2 and EU_3 are inserted in the line LE.

The line LW is provided with transmission equipment similar to that described in connection with the line LE, including an attended repeater WA_y, an associated rectifier WR_y, and an alarm WS_y at station Y. It also includes an attended repeater WA_x an associated rectifier WR_x and an alarm WS_x at station X. The actuation of the alarm WS_y at station Y indicates failure at station Y or some point to the east thereof, and failure of operation of the alarm WS_x at station X indicates failure at station X or some point to the east thereof. Intermediate repeaters WU_1, WU_2 and WU_3 are connected with the line LW at the points, 1, 2 and 3, respectively.

In order to indicate failure of an unattended station and to enable the attendant at the attended station to locate the position of the repeater which has failed, provision is made for applying certain testing frequencies to the system so that these frequencies will be transmitted over certain sections of the lines LE and LW in tandem. For this purpose generators XG_1, XG_2 and XG_3 generating frequencies f_1, f_2 and f_3, are connected to the line LE at station X on the output side of the repeater EA_x. The corresponding receiving equipment is bridged across the line LW at the point *b* of station X. This receiving equipment comprises three filters F individually selective of frequencies f_1, f_2 and f_3 and three corresponding rectifiers R which rectify the selected frequencies and cause the operation of direct current indicators in the output circuits of the rectifiers.

At station 1 a cross-connection is established between the output circuit of repeater EU_1 in line LE to the input circuit of the repeater WU_1 in line LW through a filter F_1 which is selective of the frequency f_1. At station 2 a similar cross-connection extends from the output of repeater EU_2 to the input of repeater WU_2 through filter F_2 selective of frequency f_2. So also, at station 3, a cross-connection extends from the output of the unattended repeater EU_3 to the input of the unattended repeater WU_3 through a filter F_3 selective of the frequency f_3. The filters included in these cross-connections should be made very sharply selective (as, for example, by using one or more crystal elements) in order to avoid introducing crosstalk between the oppositely directed transmissions. The loss in each filter for the passed frequency should be made substantially equal to the loss of one line section between the repeaters, as otherwise the frequency passed through the filter would arrive at the input of the repeater on the return side of the circuit without any loss in amplitude and might overload the repeater. By making the loss of the filter about equal to that of one line section the passed frequency transmitted from the path in one direction, across to the return path in the other direction, will arrive at the latter with about the same amplitude it would have, had it been transmitted over a line section to a succeeding repeater.

With the arrangement above described, the frequency f_1 will pass from station X, over the first line section of line LE, through the repeater EU_1, across the cross-connection including the filter F_1, back through the repeater WU_1, over the line section of line LW to the station X, and thence into its proper signal indicating circuit through the filter F which is selective of frequency f_1. Similarly, the frequency f_2 is transmitted from the point *a* at station X, through the repeaters EU_1 and EU_2, thence across the cross-connection including filter F_2 and back through repeaters WU_2 and WU_1 to the point *b* at station X. So also, the frequency f_3 is transmitted from the point *a*, through repeaters EU_1, EU_2 and EU_3, thence across the cross-connection through filter F_3 and back through repeaters WU_3, WU_2 and WU_1, to point *b*.

It will now be evident that the failure of different repeaters will be indicated as set forth in the following chart.

Received frequencies at *b*	Inoperative repeater
f_1, f_2, f_3	None.
f_1, f_2	EU_3 or WU_3.
f_1	EU_2 or WU_2.
None	EU_1 or WU_1.

It will be noted that the indication given in the foregoing chart only tells the attendant at station X the unattended repeater station at which a repeater has failed. For example, if the repeater EU_2 should fail frequencies f_2 and f_3 would not be received, but the attendant would not know whether it was the repeater EU_2 or WU_2 which had failed as the failure of either of these repeaters would result in blocking frequencies f_2 and f_3. However, the attendant by ascertaining that the alarm ES_y at station Y had indicated that the trouble was on the line LE, would know that it was the repeater EU_2 which had failed. In practice, however, it may prove desirable, when a repeater fails on the line transmitting in one direction, to replace not only that repeater but the repeater at the same station on the line transmitting in the opposite di-

rection, in which case the indication given in the chart will be sufficient to give the attendant all the information he needs.

The received indication of failure may represent either the failure of the amplifier or the failure of the line section immediately preceding it. It would be possible to distinguish between these two types of failures by a D. C. test made in the manner ordinarily employed for telephone cables.

The arrangement of Fig. 1 involves a scheme in which three frequencies serve for indications in both directions of transmission for three unattended repeater stations. Fig. 2 illustrates an arrangement similar to that of Fig. 1, except that only two frequencies are employed instead of three. The arrangement of the repeaters in Fig. 2 is identical with that of Fig. 1, and so also, the rectifiers and alarm arrangements associated with the outputs of the four attended repeaters at stations X and Y are identical with those shown in Fig. 1. The application of the testing frequency is, however, somewhat different. A generator XG_1 generating a frequency f_1 is connected to the line LE at the point *a* at station X, and a bridge is connected at the point *c* of the line LE at station Y, said bridge including parallel filters F selective of frequencies f_1 and f_2, respectively, said filters being connected to corresponding rectifiers R having direct current indicators in their output circuits. Similarly, a generator YG_2 generating a frequency f_2 is connected at *d* to the line LW at station Y, while a bridge circuit is connected at point *b* to the line LW at station X. Said bridge circuit includes parallel filters F selective of frequencies f_1 and f_2, and associated rectifiers and indicators identical with those at station Y.

The cross-connections between the two sides of the circuit in Fig. 2 are also somewhat different from those of Fig. 1. For example, a cross-connection including a filter F_1 selective of frequency f_1 is bridged from the output side of repeater EU_1 at station 1 to the input side of repeater WU_1 at station 1. Another cross-connection is bridged from the output side of repeater WU_3 at station 3 to the input side of repeater EU_3 at station 3, this cross-connection including a filter F_3 selective of frequency f_2. No cross-connection is established at repeater station 2.

The frequency f_1 is transmitted from point *a* over the first line section of line LE and through the repeater EU_1 at the output of which it divides, part flowing over the remainder of the line including the repeaters EU_2 and EU_3, into the filter F at station Y selective of the frequency f_1. Part of the energy of frequency f_1 on the output side of repeater EU_1 flows through the filter F_1, through the westbound repeater WU_1, and over the line section of LW to point *b* where it enters the bridge and passes through the filter F selective of the frequency f_1 at station X. Similarly, the frequency f_2 is transmitted from the point *d* in the line LW at station Y, over one section of the line and through the repeater WU_3 where the energy is divided, part of it passing on over the line LW through the repeaters WU_2 and WU_1, to the point *b* where it enters the bridge connection and passes through the filter F selective of the frequency f_2. The other part of the energy of frequency f_2 on the output side of the repeater WU_3 passes through the filter F_3 in the cross-connection to the input side of the repeater EU_3, through said repeater and over a line section of line LE to the point *c* where it enters the bridge connection and passes through the filter F selective of frequency f_2 at station Y.

Inspection of this arrangement will show that the indications provided are as follows:

Received frequencies at *b*	Received frequencies at *c*	Inoperative repeater
f_1, f_2	f_1, f_2	None
f_2	f_2	EU_1
f_1, f_2	f_2	EU_2
f_1, f_2	None	EU_3
f_1	f_1	WU^3
f_1	f_1, f_2	WU^2
None	f_1, f_2	WU_1

Thus a knowledge of the frequencies received at the two ends of the circuit in Fig. 3 permits an exact determination of the location of failure as between all six of the unattended repeaters involved. It has a slight disadvantage, however, that the attendant at one of the attended stations X or Y, must ascertain from the attendant at the other of said stations what frequencies are being received there before having the necessary information to identify the location of the failure.

In the arrangements which have been described in Figs. 1 and 2, the testing frequencies have been passed through or around the unattended repeaters without being used to produce new frequencies or combinations of frequencies at such points.

Fig. 3 shows an arrangement in which the test frequencies are modulated at certain of the unattended repeater points in order to secure new frequencies or combinations. This affords an advantageous method of obtaining indications where the number of unattended repeaters in a section is large, and where it is desired to limit the number of test frequencies employed. Thus, for example, in Fig. 3 there is illustrated an arrangement in which two different frequencies f_1 and f_2 serve to furnish indications for a total of six unattended repeater stations involving a total of twelve repeaters. This result is obtained by a method similar to that of Fig. 1, except that combinations of frequencies f_1 and f_2 (f_1+f_2, $2f_1+f_2$, etc.) are derived at certain of the unattended repeaters.

In Fig. 3 frequencies f_1 and f_2 are applied to the line LE at the point *a* at station X. At the point *b* of line LW at station X a bridge circuit is connected in which six parallel filters F, one corresponding to each unattended repeater point, are arranged. These filters are selective of frequencies f_1, f_2, f_1+f_2, f_1-f_2, $2f_1+f_2$ and $2f_1-f_2$. A cross-connection is provided at unattended repeater station 1 between the output of repeater EU_1 and the input of repeater WU_1; said cross-connection including the filter F_1, selective of frequency f_1. A similar cross-connection is made at unattended repeater station 2 through the filter F_2 selective of frequency f_2. At unattended repeater station 3 a cross-connection extends from the output of repeater EU_3 to the input of repeater WU_3. This cross-connection includes a filter F_3 which selects both frequencies f_1 and f_2. On the output side of the filter is a modulator M_3 which modulates the two frequencies f_1 and f_2. On the output side of the modulator is another filter F'_3 which selects from the various components in the output of the modulator M_3, the particular frequency f_1+f_2 which

passes back to the point *b* through the repeaters WU_3, WU_2 and WU_1. At the unattended repeater station 4 is a cross-connection similar to that shown at station 3, except that in this case the filter F'_4 is selective of the modulation component f_1-f_2 which is transmitted back over line LW through repeaters WU_4 to WU_1, inclusive. At unattended repeater station 5 is a cross-connection similar to that at station 3, except that the filter F'_5 selects the modulation component $2f_1+f_2$ which passes back to the point *b* through the repeaters WU_5 to WU_1, inclusive. At station 6 is still another cross-connection similar to that of station 3, except that the filter F'_6 selects the modulation component $2f_1-f_2$ which is transmitted back over the line LW through all six unattended repeaters.

Inspection of the arrangement of Fig. 3 will show that the indications provided are as follows:

Frequencies received at *b*						Inoperative
f_1	f_2	f_1+f_2	f_1-f_2	$2f_1+f_2$	$2f_1-f_2$	None
f_1	f_2	f_1+f_2	f_1-f_2	$2f_1+f_2$	---	EU_6 or WU_6
f_1	f_2	f_1+f_2	f_1-f_2	---	---	EU_5 or WU_5
f_1	f_2	f_1+f_2	---	---	---	EU_4 or WU_4
f_1	f_2	---	---	---	---	EU_3 or WU_3
f_1	---	---	---	---	---	EU_2 or WU_2
---	---	---	---	---	---	EU_1 or WU_1

In this system, as in Fig. 1, the attendant at station X will, from the indication on his indicators only, know at what repeater point one of the two oppositely bound repeaters has failed. He can ascertain the particular repeater which has failed, however, at that point by ascertaining from the attendant at station Y whether the line indicators show that the fault is on line LE or on line LW.

It will be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated, without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. In a signaling system, a pair of transmission lines transmitting in opposite directions between attended stations, a plurality of unattended repeater stations between said attended stations and each having repeaters in each of said transmission lines, means to apply a plurality of test frequencies to said transmission lines, cross-connections between said transmission lines so associated with said lines as to form different paths over portions of said lines for said test frequencies, said cross-connections being so located with respect to said unattended repeater stations and the repeaters thereat that different frequency paths will be disabled upon the failure of repeaters at different unattended repeater stations, and indicating means associated with the ends of said test frequency paths to indicate the failure of particular paths, whereby the combination of paths which are indicated as not having failed will serve to identify the unattended repeater station at which a repeater has failed.

2. In a signaling system, a pair of transmission lines transmitting in opposite directions between attended stations, a plurality of unattended repeater stations between said attended stations and each having repeaters in each of said transmission lines, means to apply a plurality of test frequencies to said transmission lines, cross-connections between said transmission lines so associated with said lines as to form different paths over portions of said lines for said test frequencies, said cross-connections being so located with respect to said unattended repeater stations and the repeaters thereat that different frequency paths will be disabled upon the failure of repeaters at different unattended repeater stations, indicating means associated with the ends of said test frequency paths to indicate the failure of particular paths, whereby the combination of paths which are indicated as not having failed will serve to identify the unattended repeater station at which a repeater has failed, and means associated with said transmission lines at attended stations to indicate that a failure has occurred ahead of an attended station.

3. In a signaling system, a pair of transmission lines transmitting in opposite directions between attended stations, a plurality of unattended repeater stations between said attended stations and each having repeaters in each of said transmission lines, means to apply a plurality of test frequencies to said transmission lines, cross-connections between said transmission line at each unattended repeater station, each cross-connection being selective of a different frequency so as to form different paths over portions of said lines for test frequencies, said cross-connections being so located with respect to said unattended repeater stations and the repeaters thereat that failure of a repeater at a particular unattended repeater station results in disabling the path of a test frequency characteristic of that station, and indicating means associated with the ends of said test frequency paths to indicate the failure of particular paths, whereby the combination of paths which are indicated as not having failed will serve to identify the unattended repeater station at which a repeater has failed.

4. In a signaling system, a pair of transmission lines transmitting in opposite directions between attended stations, a plurality of unattended repeater stations between said attended stations and each having repeaters in each of said transmission lines, means to apply a plurality of test frequencies to said transmission lines, cross-connections between said transmission lines at each unattended repeater station, each cross-connection being selective of a different frequency so as to form different paths over portions of said lines for test frequencies, said cross-connections being so located with respect to said unattended repeater stations and the repeaters thereat that failure of a repeater at a particular unattended repeater station results in disabling the path of a test frequency characteristic of that station, indicating means associated with the ends of said test frequency paths to indicate the failure of particular paths, whereby the combination of paths which are indicated as not having failed will serve to identify the unattended repeater station at which a repeater has failed, and means associated with said transmission lines at attended stations to indicate that a failure has occurred ahead of an attended station.

5. In a signaling system, a pair of transmission lines transmitting in opposite directions between attended stations, a plurality of unattended repeater stations between said attended stations and each having repeaters in each of said transmission lines, means to apply to one of said transmission lines at one attended station a plurality of test frequencies equal in number to said unattended repeater stations, there being one frequency characteristic of each unattended re-

peater station, indicating means associated with the other of said transmission lines at said attended station, said indicating means being selectively indicative of the failure of the frequency characteristic of any unattended repeater station, and cross-connections between said transmission lines at each unattended repeater station, each cross-connection being selective of a different frequency so as to form different paths over portions of said lines for said test frequencies, whereby the combination of frequencies indicated as not having failed will serve to identify an unattended repeater station at which a repeater has failed.

6. In a signaling system, a pair of transmission lines transmitting in opposite directions between attended stations, a plurality of unattended repeater stations between said attended stations and each having repeaters in each of said transmission lines, means to apply to one of said transmission lines at one attended station a plurality of test frequencies equal in number to said unattended repeater stations, there being one frequency characteristic of each unattended repeater station, indicating means associated with the other of said transmission lines at said attended station, said indicating means being selectively indicative of the failure of the frequency characteristic of any unattended repeater station, cross-connections between said transmission lines at each unattended repeater station, each cross-connection being selective of a different frequency so as to form different paths over portions of said lines for said test frequencies, whereby the combination of frequencies indicated as not having failed will serve to identify an unattended repeater station at which a repeater has failed, and means associated with said transmission lines at attended stations to indicate that a failure has occurred ahead of an attended station.

7. In a signaling system, a pair of transmission lines transmitting in opposite directions between attended stations, a plurality of unattended repeater stations between said attended stations and each having repeaters in each of said transmission lines, means to apply to one of said transmission lines at one attended station a plurality of test frequencies less in number than the number of unattended repeater stations, cross-connections between said transmission lines at each unattended repeater station, certain of said cross-connections being selective of said test frequencies and other of said cross-connections having means to produce and being selective of other frequencies derived from said test frequencies so that there will exist different paths over said lines for different frequencies characteristic of each unattended repeater station, and indicating means associated with the other of said transmission lines at said attended station, said indicating means being selectively indicative of the failure of the frequency characteristic of any unattended repeater station, whereby the combination of frequencies indicated as not having failed will serve to identify an unattended repeater station at which a repeater has failed.

8. In a signaling system, a pair of transmission lines transmitting in opposite directions between attended stations, a plurality of unattended repeater stations between said attended stations and each having repeaters in each of said transmission lines, means to apply to one of said transmission lines at one attended station a plurality of test frequencies less in number than the number of unattended repeater stations, cross-connections between said transmission lines at each unattended repeater station, certain of said cross-connections being selective of said test frequencies and other of said cross-connections having means to produce and being selective of other frequencies derived from said test frequencies so that there will exist different paths over said lines for different frequencies characteristic of each unattended repeater station, indicating means associated with the other of said transmission lines at said attended station, said indicating means being selectively indicative of the failure of the frequency characteristic of any unattended repeater station, whereby the combination of frequencies indicated as not having failed will serve to identify an unattended repeater station at which a repeater has failed, and means associated with said transmission lines at attended stations to indicate that a failure has occurred ahead of an attended station.

9. In a signaling system, a pair of transmission lines transmitting in opposite directions between attended stations, a plurality of unattended repeater stations between said attended stations and each having repeaters in each of said transmission lines, means to apply to one of said transmission lines at one attended station a test frequency, a cross-connection between said transmission lines at an unattended repeater station, said cross-connection being selective of said test frequency so as to provide a return path for said test frequency back to said attended station over the other transmission line as well as a path to the second attended station over said first transmission line, means to apply to said second transmission line at said second attended station a second test frequency, a cross-connection between said transmission lines at another unattended repeater station, said cross-connection being selective of said second test frequency so as to provide a return path therefor back to said second attended station over said first transmission line as well as a path to said first attended station over said second transmission line, and means associated with each of said lines at each of said attended stations to selectively indicate the reception of either or both of said test frequencies, whereby the combination of frequencies indicated at the two attended stations as not having failed will serve to identify an unattended repeater which has failed.

10. In a signaling system, a pair of transmission lines transmitting in opposite directions between attended stations, a plurality of unattended repeater stations between said attended stations and each having repeaters in each of said transmission lines, means to apply to one of said transmission lines at one attended station a test frequency, a cross-connection between said transmission lines at an unattended repeater station, said cross-connection being selective of said test frequency so as to provide a return path for said test frequency back to said attended station over the other transmission line as well as a path to the second attended station over said first transmission line, means to apply to said second transmission line at said second attended station a second test frequency, a cross-connection between said transmission lines at another unattended repeater station, said cross-connection being selective of said second test frequency so as to provide a return path therefor back to said second attended station over said first transmission line as well as a path to said first attended station over said second transmission line, means associated

with each of said lines at each of said attended stations to selectively indicate the reception of either or both of said test frequencies, whereby the combination of frequencies indicated at the two attended stations as not having failed will serve to identify an unattended repeater which has failed, and means associated with said transmission lines at attended stations to indicate that a failure has occurred ahead of an attended station.

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