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K. LUTOMIRSKI

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SIGNAL TRANSMISSION SYSTEM

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Fig. 1

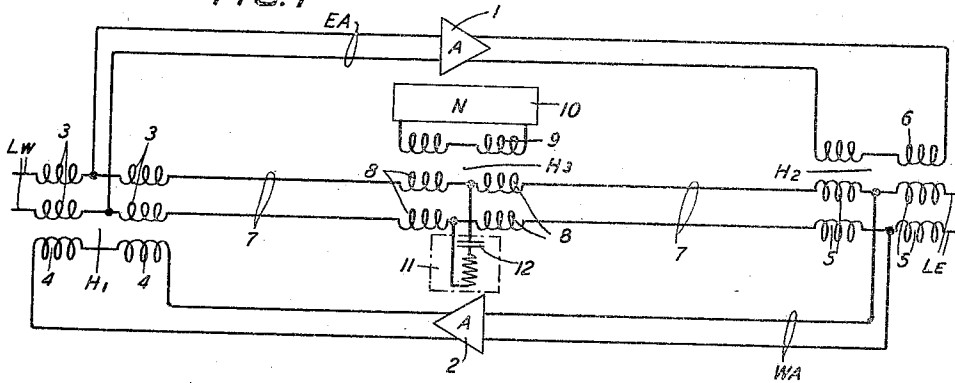


Fig. 2

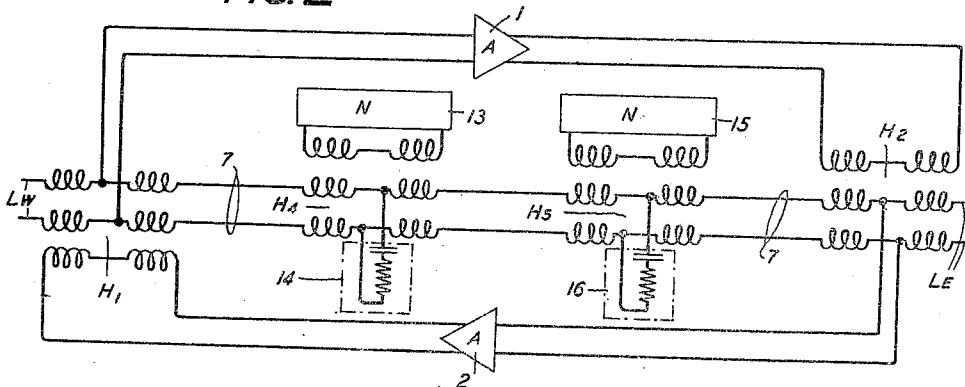
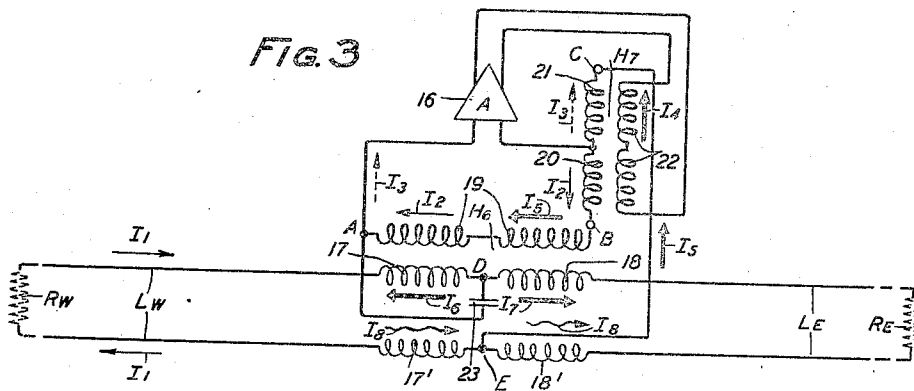


Fig. 3



INVENTOR
K. LUTOMIRSKI
BY *J. A. Burgess*
ATTORNEY

UNITED STATES PATENT OFFICE

KAREL LUTOMIRSKI, OF NEW YORK, N. Y., ASSIGNOR TO BELL TELEPHONE LABORATORIES, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

SIGNAL TRANSMISSION SYSTEM

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This invention relates to signaling systems utilized for transmitting different kinds of signals, for example, telephonic signals and direct current telegraph signals, and particularly to repeater circuits for use in such systems.

It is an object of the invention to improve the operation of systems of the above mentioned type.

The invention relates specifically to a form of repeater circuit in which the repeaters are so associated with the transmission line that there is a continuous metallic path from each conductor of the line on one side of the repeater to a corresponding conductor of the line on the other side of the repeater. Thus, without the use of auxiliary compositing apparatus, which is ordinarily quite complicated and expensive, direct currents and alternating currents of a frequency too low to be amplified efficiently by the repeaters provided to amplify the higher frequency signal currents, may pass over the metallic paths between two sections of the transmission line without interfering with the action of the repeaters with respect to waves of higher frequency.

One embodiment of the invention comprises a modification of a two-way, two-element telephone repeater having the usual two oppositely directed one-way repeating paths associated with the two line sections between which telephonic signals are to be transmitted by the usual coupling circuits, such as hybrid coil transformers. The two line sections are also connected to each other through an auxiliary circuit comprising one or more hybrid coil transformers in such manner as to provide at all times a continuous metallic electrical connection between the corresponding line conductors on each side of the repeater through portions of the two coupling circuits and the transformers for the direct transmission of direct current and low frequency alternating current signals. Networks having

suitable impedance elements associated with the windings of the hybrid coil transformers are utilized to balance the impedances of the line sections, so as effectively to prevent the higher frequency signals from being transmitted between the two line sections over the auxiliary circuit and to simulate the line impedance so as to prevent the repeater from feed back and singing.

A modification of the invention is a one-way, one-element repeater comprising a single amplifier and two hybrid coil transformers associated with the transmission line in such manner as to produce a larger amplification for the higher frequency signals in the direction of transmission than could be obtained with either the ordinary 22 type or 21 type repeater, and at the same time so as to provide a continuous metallic path over the transmission line for direct current or lower frequency alternating current signals.

The invention itself and its objects and advantages will be shown more clearly by reference to the following detailed description in connection with the accompanying drawing in which:

Figs. 1 and 2 show diagrammatically two-way, two-element telephone repeater circuits embodying the invention; and

Fig. 3 shows diagrammatically a one-way one-element telephone repeater circuit embodying the invention.

The circuit of Fig. 1 comprises a west two-way line section L_w and an east two-way line section L_E associated by means of hybrid coil transformers H_1 and H_2 in the manner well known in the art with a one-way circuit EA including the one-way amplifying device 1 for impressing on line section L_E in amplified form telephonic signals received over line section L_w , and with a one-way circuit WA including the one-way amplifying device 2 for impressing on line section L_w in amplified form telephonic signals received over line section L_E . The hybrid coil

transformer H_1 comprises the usual line windings 3 in series with the line conductors of line section L_W and the usual series winding 4 inductively coupled with the line windings 3, and the hybrid coil transformer H_2 comprises the usual line windings 5 in series with the line conductors of line section L_E and the usual series winding 6 inductively coupled with the line windings 5. The input of the amplifying path EA is connected across the bridge points between the line windings 3 of hybrid coil H_1 and the output of that path is connected across the terminals of the series winding 6 of hybrid coil transformer H_2 . Similarly, the input of the amplifying path WA is connected across the bridge points between the line windings 5 of hybrid coil transformer H_2 and the output of that path is connected across the terminals of the series winding 4 of hybrid coil transformer H_1 .

The corresponding line conductors of the line sections L_W and L_E are also connected to each other over continuous metallic paths comprising the conductors 7, the line windings 3 of hybrid coil transformer H_1 , the line windings 5 of hybrid coil transformer H_2 and the line windings 8 of a third hybrid coil transformer H_3 in series in the conductors 7 between hybrid coils H_1 and H_2 . Connected to the series winding 9 of hybrid coil H_3 is an impedance network 10 and connected across the bridge points between the line windings 8 of hybrid coil transformer H_3 is a second impedance network 11 including the series condenser 12.

For the purpose of this invention it is assumed that the two line sections L_W and L_E in the system of Fig. 1 are so constructed that their effective impedances looking from the hybrid coil transformer H_3 are approximately equal. The impedance elements of networks 10 and 11 in accordance with the invention are chosen so that these networks effectively balance the impedances of line sections L_W and L_E through the hybrid coil H_3 .

The operation of the system of Fig. 1 for signal transmission in the direction from west to east is similar to that in the direction from east to west, so that the former need only be described.

It will be assumed that alternating signal currents of certain frequencies to be amplified, for example, currents of telephonic frequencies, are being received over the line section L_W . A portion of these currents will be transmitted from the line windings 3 of hybrid coil H_1 into the input of the one-way amplifying path EA through the connections thereof across the bridge points between the line windings 3, and will be amplified by the one-way amplifier 1 in that path. The telephonic currents passing through the line winding 3 of hybrid coil H_1 will cause a current to be induced in the series winding 4

thereof, which current will be dissipated in the output of the one-way amplifier 2 in the amplifying path WA.

If the networks 10 and 11 are properly designed so as to balance the effective impedance of line section L_W through hybrid coil H_3 , none of the telephonic currents received over line section L_W will be transmitted over the continuous metallic circuit connecting line sections L_W and L_E , comprising the line windings 3 of hybrid coil 3, the line winding 8 of hybrid coil H_3 , the line windings 5 of hybrid coil H_2 and the connecting conductors 7.

A portion of the amplified signaling current in the output of amplifier 1 in the path EA will be impressed by the hybrid coil H_2 on the east line section L_E and will be transmitted thereover in the direction from west to east. Another portion of the amplified current from the output of amplifier 1 will be impressed by the hybrid coil H_2 on the input of hybrid coil H_3 through the conductors 7 and the line windings 5 of hybrid coil H_2 . This amplified current will be divided by the hybrid coil H_3 between the associated series and shunt circuits and will be dissipated in the networks 10 and 11, respectively, therein. If the networks 10 and 11 are properly designed to balance the effective impedance of the line section L_E through the hybrid coil H_3 , none of the amplified current will be transmitted through hybrid coil H_3 over the conductors 7 to the left of the coil H_3 and the series windings of hybrid coil H_1 to the west line section L_W .

The impedance looking into the hybrid coil H_3 is, due to the proper design of networks 10 and 11, equal to the effective line impedance L_E so that none of the amplified current from the output of amplifier 1 in the amplifying path EA will be impressed by hybrid coil H_2 on the input of amplifier 2 in the amplifying path WA.

However, direct current signals received over the line section L_W in the direction from west to east, or over the line section L_E in the direction from east to west, will be transmitted around the repeating paths EA and WA to the line section L_E or to the line section L_W over the continuous metallic paths extending between the two line sections and including the line windings 3 of hybrid coil H_1 , line windings 5 of hybrid coil H_2 , the line windings 8 of hybrid coil H_3 and the connecting conductors 7.

The circuit of Fig. 1 may be designed by proper choice of the particular impedance elements of networks 10 and 11 so as to completely balance the impedance of line sections L_W and L_E when the received alternating current waves to be amplified comprise frequencies within the range which can be efficiently amplified by amplifying devices 1 and 2, so as to allow alternating current

signals of lower frequencies as well as the direct current signals to be transmitted around the repeater through the conductive metallic paths between the line section L_W and L_E . The capacity of the series condenser 12 in the network 11 is made of such value as to prevent the by-passing of the direct current and low frequency alternating current signals through the shunt network 11.

The system of Fig. 2 differs from that of Fig. 1 merely in the provision of two intermediate hybrid coil transformers H_4 and H_5 associated with the conjugately related impedance networks 13, 14 and 15, 16 respectively, in place of the single intermediate hybrid coil transformer H_3 and associated impedance networks 10, 11 in the system of the latter figure. Impedance elements 13 and 14 are so chosen that the networks will balance the effective impedance of line section L_W through hybrid coil H_4 , and the impedance elements in networks 15 and 16 are chosen so that these networks will balance the effective impedance of line section L_E through hybrid coil H_5 , when the received alternating current signal waves comprise frequencies within the range which may be efficiently amplified by the amplifiers 1 and 2. The by-passing of signal waves of those frequencies in either direction between the line sections L_W and L_E through the conductive metallic paths between these line sections, comprising the line winding of hybrid coil transformers H_1 , H_4 , H_5 and H_2 , and the connecting conductors 7 is thereby prevented.

The system of Fig. 2 has all the advantages of the system of Fig. 1 as regards enabling the by-passing of direct current and low frequency alternating current signals around the repeating paths over continuous metallic circuits and in addition the advantage that the effective impedances of line sections L_W and L_E need not be equal. The system of Fig. 2, of course, requires more apparatus than that of Fig. 1.

Fig. 3 shows an application of the invention to a repeating circuit in a one-way signal transmission system. This repeating circuit is similar to the well-known 21-type repeater but differs therefrom in that, besides providing a continuous metallic circuit for the transmission of direct current and low frequency alternating current signals over the transmission line around the repeater in both directions as obtained by the 21-type repeater, it has additional advantages from the standpoint of elimination of echoes and increased amplification in one direction of transmission.

The repeating circuit of Fig. 3 includes a single one-way amplifying element 16 and two hybrid coils or 3-winding transformers H_6 and H_7 . The hybrid coil H_6 comprises two equal windings in series, 17, 17' and 18, 18'

and a third winding 19 inductively coupled therewith. The two windings 17, 17' and 18, 18' are connected in series between the two parts L_W and L_E of a transmission circuit, such as, for example, a telephone line, the terminating impedances of which are indicated by the dotted resistances R_W and R_E , respectively. Hybrid coil H_7 comprises two equal windings 20 and 21 in series and a third winding 22 inductively coupled therewith.

The output terminals of the amplifier 16 are connected to the third winding 22 of hybrid coil H_7 . The input terminals of the amplifier 16 are connected across the terminals of a circuit including winding 19 of hybrid coil H_6 and winding 20 of hybrid coil H_7 in series. The windings 21 and 20 of hybrid coil H_7 , the winding 19 of hybrid coil H_6 and a condenser 23 are connected in series across the transmission circuit L_W — L_E at the junction points D and E between the windings 17, 17' and 18, 18'.

In order to prevent amplifier 16 from getting in a singing condition, it is desirable that the amplifier circuit be terminated between the points A and B, which are the terminals of winding 19, and between the points A and C in the bridge circuit, in substantially the same impedance. One way of accomplishing this is by making the impedance ratio between the windings 17, 17' and 18, 18' and the third winding 19 of hybrid coil H_6 approximately 4 to 1. For if L_W equals L_E equals R , then the impedance A to C (neglecting condenser 23 and the resistances of the windings 17, 17' and 18, 18') equals

$$\frac{R}{2}$$

Therefore, to make the impedances on both sides of the hybrid coil H_7 in the amplifier circuit the same, the impedance A to B should be

$$\frac{R}{2}$$

also. This may be accomplished as stated above by using for a hybrid coil H_6 a coil which has a ratio 4 to 1 between windings 17, 17' and 18, 18' and winding 19.

In order to obtain maximum gain for the amplifier 16, it is desirable that the impedance ratio of the transformer H_7 be such as to match the internal impedance of the amplifier to the terminating impedances A—B and A—C.

The operation of the system of Fig. 3 will now be described.

Let it be assumed a signal current I_1 enters the repeater from the line section L_W in the direction indicated by the light straight arrow labeled I_1 . The input current I_1 will be divided equally between the windings 17 and 17' of hybrid coil H_6 and the bridge circuit connected across the bridge points D, E of the

transmission line. The portion of current I_1 transmitted through the windings 17 and 17' will induce a current I_2 of the same magnitude as I_1 in the winding 19 of the transformer in the direction indicated by the light straight arrow labeled " I_2 ". This current I_2 will circulate over the path extending from the right-hand terminal B of winding 19, through winding 19, left-hand terminal A of that winding, the input circuit of amplifier circuit 16, mid-point between windings 20 and 21 of hybrid coil H_7 , and through winding 20 back to the terminal B of winding 19.

The portion of the input current transmitted into the bridge circuit, which will be referred to as I_3 , will be transmitted in the direction indicated by the dotted arrows labeled " I_3 " over the path extending from the junction point D in the upper wire of the transmission line through condenser 23, terminal A of winding 19 through the input circuit of amplifier 16 to the mid-point between windings 20 and 21 of hybrid coil H_7 , and through winding 21 to the junction point E in the lower wire of the transmission line, line winding 17' of hybrid coil transformer H_6 , lower wire of line section L_W , terminating impedance R_W , upper wire of line section L_W , line winding 17 of hybrid coil H_6 to the junction point D of the transmission line.

None of the input current will flow through the east line section L_E as the impedance across D—E is equal to the impedance looking into winding 17 and 17'.

As indicated by the arrows in Fig. 3 the current I_3 when passing through the input circuit of amplifier 16 is in such direction as to be superimposed upon the current I_2 therein, but the current I_3 is transmitted through winding 21 in the direction opposite to that of the current I_2 in winding 20. As the currents I_2 and I_3 are of equal magnitudes and oppose each other, the net effect in the windings 20 and 21 is such as to prevent the current being induced in the winding 22 by these currents. In other words, the transformer H_6 does not introduce a loss in the output circuit of amplifier 16.

The superposed currents I_2 and I_3 impressed on the input circuit of amplifier 16 will cause an amplified current I_4 to be produced in the output of the amplifier. The amplified current I_4 will flow through winding 22 of hybrid coil H_7 in the direction indicated by the heavy straight arrow labeled " I_4 ", and will induce a current I_5 in windings 20 and 21 of hybrid coil H_7 , the value of which will be determined by the impedance ratio between winding 22 and windings 20 and 21. Current I_5 will flow in the direction indicated by the heavy straight arrow labeled " I_5 " over the path extending from the bridge point E in the transmission line through the windings 21 and 20 of hybrid coil H_7 , winding 19 of hybrid coil H_6 and condenser 23 to the bridge

point D of the transmission line where it will be divided in equal currents I_7 and I_8 flowing in the direction indicated by the heavy straight arrows so labeled, respectively, over the parallel paths comprising windings 18 and 18' and the terminating impedance R_E of line section L_E , and windings 17 and 17' and terminating impedance R_W of line section L_W back to the junction point E.

The current I_5 transmitted through winding 19 of hybrid coil H_6 will induce an equal current I_8 in the windings 17, 17' and 18, 18' which will flow in the transmission line L_W — L_E in the same direction as indicated by the wavy arrows labeled " I_8 " as the input current I_1 . This amplified current I_8 flows in the west line section L_W in the opposite direction to the amplified current I_6 therein, and in the east line section L_E in the same direction as the amplified current I_7 therein. The amplified current I_8 by proper design of the repeater circuit may be made of such value as to neutralize the amplified current I_6 , thus effectively eliminating the transmission of amplified echoes towards the talker in the transmission line, and to reinforce the amplified current I_7 in the direction of signal transmission and thus effectively increasing the amplification of the signaling currents transmitted over the transmission line towards the listener.

An actual test which has been made of the repeater of Fig. 3 in connection with a telephone line indicates that the talker echo may be substantially eliminated and an amplification in one direction increased by about 6 decimals over that which could be obtained with a 21-type repeater or in one one-way path of a 22-type repeater having equivalent amplifying units.

The system of Fig. 3 has the additional advantage in that direct current or low frequency alternating current signals may be transmitted in either direction over a continuous metallic path between line sections L_W and L_E without interfering with the action of the repeater. The condenser 23 in the bridge circuit connected between the points D and E in the transmission line is provided for the purpose of preventing the by-passing therethrough of direct current or low frequency alternating current signals.

The invention should not be construed as limited to the particular repeating circuits and systems described, inasmuch as these systems and circuits may be modified greatly by persons skilled in the art without departing from the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. In combination in a signal transmission system, two two-way line sections, two oppositely directed one-way repeating paths, means coupling said one-way repeating paths to said two-way line sections in condition to

repeat alternating current signal waves of frequencies comprised in a given range in opposite directions therebetween, means providing a continuous conductive connection between said two-way line sections, and means for effectively balancing the impedances of said two-way line sections through the last mentioned means.

2. In combination in a signal wave transmission system, two two-way line sections, two oppositely directed one-way paths each including amplifying means, means coupling said one-way paths to said two-way line sections in condition to repeat alternating current signal waves comprising a given range of frequencies in opposite directions therebetween, means providing a continuous metallic circuit connection for the transmission of waves directly between said two-way line sections, and means for effectively balancing the impedances of said two-way line sections through the last-mentioned means, so as to substantially prevent the transmission of said signal waves between said two-way line sections over said metallic circuit connection while allowing transmission therebetween of direct current signal waves and alternating current waves of frequencies outside said given range.

3. In combination in a signal transmission system, two two-way line sections, oppositely directed one-way paths including amplifying means, means coupling said one-way paths to said two-way line sections in condition to repeat alternating current signal waves of certain frequencies in opposite directions therebetween, and a circuit connecting said line sections, said circuit comprising a hybrid coil transformer having line windings connected effectively in series with the conductors of both of said line sections so as to form continuous conductive paths therebetween and a series winding inductively coupled to said line windings, a network connected across the series winding of said hybrid coil transformer and a second network connected across the bridge points between the line windings of said transformer.

4. The combination of claim 3 and in which the effective impedances of said line sections looking into said transformer, of said network connected across said series winding and of said second network are such as to form a balanced bridge circuit which prevents transmission of signal waves of said certain frequencies between said two-way line sections over said conductive paths while allowing transmission thereover of other waves.

5. The combination of claim 3 and in which said second network includes means for preventing the by-passing therethrough of direct current waves and low frequency alternating current waves.

6. The combination of claim 3 and in which said second network includes a series con-

denser for preventing the by-passing of direct current between the bridge points between the line windings of said transformer.

7. The combination of claim 1 and in which said balancing means comprises a hybrid coil transformer associated with said continuous conductive connection, and balancing networks operating through said transformer.

8. The combination of claim 1 and in which said balancing means comprises two impedance networks coupled in energy transmitting relation with said continuous connection and in conjugate relation with each other.

9. The combination of claim 1 and in which said balancing means comprises two balancing networks of substantially equal impedance coupled in energy transmitting relation with said continuous connection, and in conjugate relation with each other.

10. The combination of claim 1 and in which said balancing means comprises a hybrid coil transformer having line windings in series in said continuous connection and a series winding inductively coupled with said line windings, a balancing network connected across the terminals of said series winding and another balancing network connected across the bridge points between said line winding.

11. The combination of claim 1 and in which said coupling means comprises two hybrid coil transformers, and said balancing means comprises a third hybrid coil transformer having line windings in series in said continuous connection and a series winding inductively coupled with said line winding, an impedance network connected across the terminals of said series winding, and another impedance network connected across the bridge points between said line winding, the impedance networks containing such impedance elements as to balance the effective impedances of said two-way line sections through said transformer and effectively to prevent transmission between said two-way line sections of waves of frequencies in said given range over said continuous conductive connection.

12. In combination in a signal transmission system, two two-way signaling line sections, oppositely directed one-way paths including amplifying means, means coupling said one-way paths to said two-way line sections in condition to repeat alternating current signal waves of certain frequencies therebetween, two hybrid coil transformers connected between the coupling means associated with the respective two-way line sections, each having series and line windings, the line windings of the two transformers being connected in series with each other and with the line wires of said two-way line sections so as to provide continuous conductive paths therebetween, and means associated with each transformer to balance the impedance of a different one of

the two-way line sections, so as to prevent transmission of signal waves of said certain frequencies between said line sections over said conductive paths therebetween while allowing transmission thereover between said line sections of direct current waves and alternating current waves of other frequencies.

In witness whereof, I hereunto subscribe my name this 3rd day of July, 1930.

KAREL LUTOMIRSKI.

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