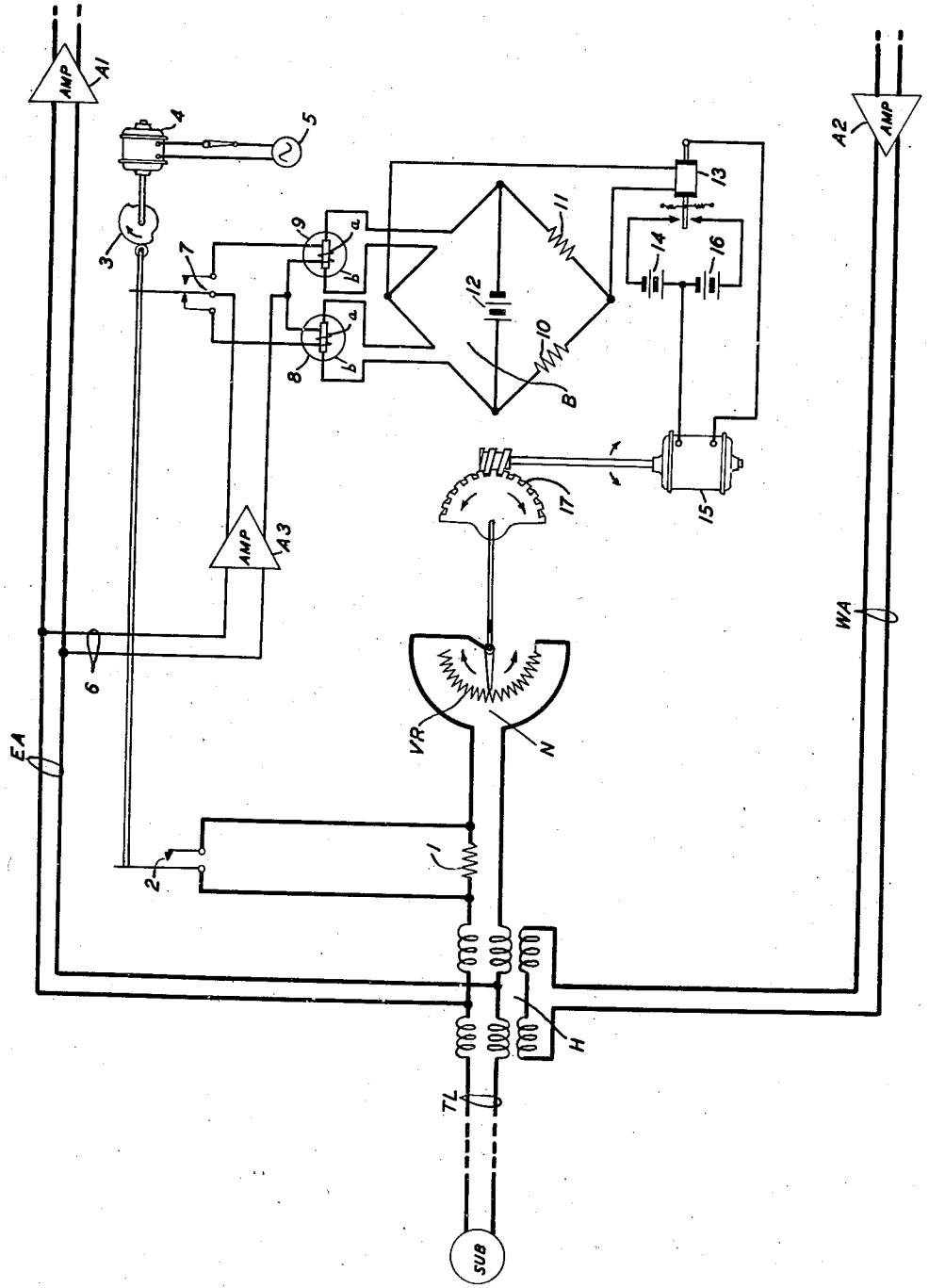
Dec. 1, 1942. H. A. AFFEL 2,303,419

TWO-WAY SIGNAL TRANSMISSION SYSTEM

Filed June 6, 1941



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Patented Dec. 1, 1942 2,303,419

UNITED STATES PATENT OFFICE

2,303,419

TWO-WAY SIGNAL TRANSMISSION SYSTEM

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Application June 6, 1941, Serial No. 396,825

7 Claims. (Cl. 178—44)

The invention relates to a two-way signal transmission system and particularly to such a system including a two-wire transmission line or circuit adapted to transmit in both directions and an adjoining two-way transmission link, such as a four-wire circuit, which provides separate one-way transmission paths, one adapted for transmitting to the two-wire line and the other to transmit from the two-wire line.

An object of the invention is to so couple the adjoining line and four-wire circuit of such a system as to provide efficient and economical transmission of the signals between them with a minimum of echo and singing difficulties for a wide range of impedance variation in the two-wire line.

In two-way telephone systems it is the usual practice to connect a two-wire line to a four-wire circuit, either physical or carrier, through a so-called hybrid coil terminating set comprising a hybrid coil coupling each side of the four-wire circuit to the two-wire line and an associated impedance network of fixed value for balancing the impedance of the connected two-wire line (perhaps in association with amplifiers to form a terminal repeater). Where the connected two-wire line is of appreciable length and of properly smooth impedance characteristic, a good balance and hence a high return loss is readily obtainable with such a terminating set, and the reflected currents returned to the far end of the four-wire circuit are seldom of sufficient magnitude to appreciably degrade the signal transmission from the standpoint of echos or potential singing difficulties. On the other hand, where the connected two-wire line is short and is subject to appreciable impedance variation due to the switching in of one or more interoffice trunks and subscribers' loops of various lengths and types, as is usually the case in setting up different telephone connections, the balance obtainable is usually poor. A low return loss results with consequent echo difficulties which may, particularly in the case of long connections, require supplemental use of voice-operated echo suppressor devices. In general, in cases of this kind, it is usual to provide a compromise balancing network, such as a simple resistance, whose impedance value is a mean of the various line impedances which may be encountered in making the usual telephone connections.

The copending patent application of D. Mitchell, Serial No. 380,425, filed February 25, 1941, discloses a system for minimizing echo difficulties for such connections without the use of echo suppressors, in which, during signal transmission from the four-wire circuit to the two-wire line, an automatic arrangement effectively balances the signal transmission in the two-wire line received over the four-wire circuit from the distant subscriber against the transmission supplied to the balancing network of the hybrid coil terminating set, and adjusts the impedance of that network in accordance with the amount and direction of the measured unbalance to improve the return loss, and during signal transmission from the two-wire line to the four-wire circuit prevents adjustment of the balancing network.

The present invention is similar to that of the aforementioned Mitchell patent application in that it employs an automatic arrangement to determine the amount of unbalance during signal transmission from the four-wire circuit to the two-wire line and to adjust the impedance of the balancing network accordingly, but the specific method and circuit arrangements for accomplishing this result are entirely different.

Applicant's arrangement, briefly described, employs a "feeling-out" circuit which periodically varies the impedance of the balancing network over a very narrow range, a "pick-up" circuit synchronized with the feeling-out circuit which during signal transmission from the four-wire circuit to the two-wire line diverts a portion of the signal energy appearing in the side of the four-wire circuit leading away from the hybrid coil, and switches it alternately between two energy storage devices in opposing sides of a measuring bridge circuit, to control the balance of the bridge, and a motor-driven circuit controlled by the unbalance of the bridge to adjust the impedance of the balance network in the proper direction and amount to balance the two-wire line.

The various objects and features of the circuit arrangement of the invention will be better understood from the following complete description when read in conjunction with the accompanying drawing, the single figure of which shows a part of a two-way telephone system embodying one modification of the invention.

Referring to the drawing, a four-wire telephone circuit, which may be a long toll telephone circuit, comprising the oppositely-directed one-way transmission paths EA and WA respectively including the one-way amplifiers A1 and A2, is coupled at one terminal by hybrid coil H and the associated line balancing network N to a two-way, two-wire telephone line TL which, as indicated, is extended to a subscriber's telephone station. The line TL may, by suitable switching apparatus (not shown), be made to include, if necessary for a given telephone connection, a number of transmission links, such as interoffice trunks and cord circuits, as is common in well-known toll telephone switching practice.

The balancing network N may consist of a single variable resistance VR, as shown, whose range is roughly that of the resistance components of the impedances of the two-wire line

TL, which will be encountered over a given period of time as the two-wire line conditions are changed in setting up the usual range of telephone connections, but may consist of a variable inductance, variable capacitance or variable combination of resistance, inductance and capacitance corresponding more exactly to the impedance characteristics of the connected line, depending on the accuracy of line impedance matching desired.

The "feeling-out" circuit of the invention consists of a small resistance or impedance element 1 in series with the variable network N on the network side of the hybrid coil H, and the associated contact switch 2 adapted to be closed periodically, several times a second, to short-circuit resistance 1, by the rotation of the cam 3 driven by the continuously operating motor 4 controlled from an alternating or direct current source 5. The values of resistance element 1 and the other elements are selected so that the alternate shunting and unshunting of the resistance 1 periodically varies, several times a second, the effective impedance of network N over a relatively narrow range sufficient to disturb the balance by a small amount, say, a fraction of a decibel.

Connected across the input of the path EA is the input of a "pick-up" circuit 6 including the one-way amplifier A3, which diverts a part of the energy flowing in the path EA. A contact switch 7 also controlled from cam 3 so as to be synchronized with switch 2, operates periodically to switch the output of the circuit 6 alternately between the heaters *a* of the two thermistors 8 and 9, each operating as an integrating circuit. The switching is so arranged that when the supplementary resistance 1 in the network circuit is shunted out, any speech or echo energy from path EA amplified in A3 is supplied as heating current to the heater *a* of thermistor 8, and when the supplementary resistance 1 is unshunted the energy from path EA amplified by A3 is supplied as heating current to the heater *a* of thermistor 9.

The thermistors 8 and 9 are identical four-terminal thermistors and their variable resistance elements *b* are connected in adjacent arms of the Wheatstone bridge circuit B having the equal linear resistance elements 10 and 11 in the other two arms; a battery 12 for supplying the energizing current for the bridge connected across one bridge diagonal; and the winding of the galvanometer relay 13 connected across the other diagonal. The bridge B is so arranged that when the currents through the heater *a* of the thermistors 8 and 9 are equal, thus making the resistance values of their variable resistance elements also equal, the bridge is balanced. For that condition, no unbalance current will flow through the winding of relay 13 and its armature will be held in the neutral position; but when the heater currents of thermistors 8 and 9 are unequal, the resistance values of the two thermistors are likewise unequal and the bridge B will be unbalanced. The unbalance current of the bridge passing through the winding of relay 13 will cause its armature to be operated either in the "up" direction or in the "down" direction depending on which thermistor 8 or 9 has the greater resistance value.

When relay 13 is operated in the "up" direction current of one polarity from battery 14 is supplied to the reversible motor 15 causing its operation in one direction, and when relay 13 is operated in the "down" direction current of the opposite polarity from battery 16 is supplied to motor 15 operating it in the reverse direction. For operation of the motor 15 in the first direction, the gearing 17 mechanically coupling the motor shaft to the movable arm of variable resistance VR in balancing network N causes the rotation of that arm in one direction, say, in the direction to reduce its resistance value and thus the effective impedance of network N, and for operation of the motor in the opposite direction it causes the movable arm to rotate in the opposite direction to increase the resistance value of VR and thus the effective impedance of network N.

Thus by the "feeling-out" action, if, when speech signals are being received over the path WA of the four-wire circuit from the distant terminal, a reduction in the impedance of network N would result in a lowering of the amount of speech energy on the network side of hybrid coil H, i. e., an improvement in balance, then the reflected speech energy, due to the unbalance of the hybrid coil set, appearing in path EA and diverted into "pick-up" circuit 6 will cause one of the thermistors 8 or 9 to have a larger resistance value than the other. This will unbalance bridge B in a direction such that the impedance of the network N will be adjusted in the manner described above in the proper direction until a degree of balance has been obtained beyond which the balance will be degraded and the speech energy in the hybrid coil circuit will again increase. An optimum balance and maximum return loss will thus be established within the limits of variation of the variable network N provided. This adjustment presumably will largely take place within a short time interval after the establishment of a given telephone connection and the arrival of the first speech energy from the far end of the four-wire circuit.

It will be apparent that when speech transmission is in the opposite direction, i. e., from the two wire line TL to the four-wire circuit, the direct speech energy from the two-wire line TL passing over the path EA will be diverted into the pick-up circuit 6 and in the manner described above will also be applied to the measuring bridge and tend to operate it so as to establish an optimum adjustment of the network N. However, within wide variations the resulting variations of the network N will in this case not affect the amount of energy received by the pick-up circuit if the impedances of the four-wire circuit have been properly designed. Therefore, the setting of the variable balancing network N will remain at the value initially established in response to the speech energy received from the talker at the distant terminal of the four-wire circuit.

The proper selection of the values of the various elements and other factors needed to provide the optional time integration and switching periods may be readily determined by experiment for a given set of conditions. It is apparent that other devices providing an impedance varying with the amount of supplied current may be used as integrators in place of the thermistors illustrated and described. Other modifications of the circuits illustrated and described which are within the spirit and scope of the invention will be apparent to persons skilled in the art.

What is claimed is:

1. In combination with a two-way signal transmission system including a two-way signal

transmission line subject to impedance variations, a four-wire signal transmission circuit consisting of oppositely directed one-way paths for the signals transmitted in opposite directions and a hybrid coil and associated line balancing network coupling one terminal of said four-wire circuit to said line, means to reduce echoes and prevent singing during signal transmission between said four-wire circuit and said line comprising switching means periodically changing the effective impedance of said balancing network by a relatively small amount, measuring means for continuously comparing the levels of the unbalance signal currents produced in said four-wire circuit during said signal transmission for the time intervals in which the effective impedance of said network is so changed with those produced in said four-wire circuit for the intermediate intervals, and a second switching means responsive to a difference of the compared unbalance currents to continuously adjust the impedance of said networks in the proper direction until the compared unbalance currents become substantially equal.

2. In combination with a two-way signal transmission system including a two-way signal transmission line subject to appreciable impedance variation, and a four-wire signal transmission circuit comprising oppositely directed one-way signal transmission paths and a hybrid coil and associated line balancing network coupling the input of one path and the output of the other in conjugate relation with each other and in signal transmitting relation with said two-way line, means to reduce echoes and singing in said four-wire circuit during signal transmission from said other path to said two-way line comprising switching means adapted to periodically change the effective impedance of said network by an amount small in comparison with the total impedance thereof, measuring means for continuously comparing the amplitudes of the unbalance currents appearing in said one path during the time intervals in which the impedance of said network is so changed with those of unbalance currents appearing in said one path during intermediate time intervals, and means responsive to a difference in the compared unbalance currents to continuously adjust the impedance of said network in the proper direction to reduce said difference.

3. The combination of claim 2 in which said measuring means comprises a Wheatstone bridge circuit including an equivalent variable impedance element in each of two opposing arms, the impedance value of which varies with the amplitude of the current supplied thereto, and means for supplying unbalance current from said one path to one of said variable impedance elements during each of the first time intervals and to the other of said variable impedance elements during each of said intermediate time intervals, said bridge circuit being balanced when the total currents supplied to the two variable impedance elements are equal and unbalanced when the supplied currents are unequal, said adjusting means being responsive to an unbalance of the bridge circuit in one direction to increase the impedance of said network and to an unbalance of the bridge circuit in the opposite direction to decrease the impedance of said network.

4. The combination of claim 2, in which said measuring means comprises a circuit for continuously diverting a portion of the currents flowing in said one path, a Wheatstone bridge circuit having equivalent variable impedance elements the impedance of each of which is adapted to vary in accordance with the amplitude of the currents supplied thereto, in each of two opposing arms and a second switching means synchronized with the first switching means for alternately connecting the output of said diverting circuit to each of said variable impedance elements, said impedance adjusting means being responsive in one direction or the other to the unbalance current of the bridge circuit depending on which variable impedance element has the greater impedance.

5. The combination of claim 2, in which said switching means comprises a small resistance connected effectively in series with said network on the network side of said hybrid coil, and means adapted to periodically short-circuit said series resistance.

6. The combination of claim 2, in which said measuring means comprises a circuit for continuously diverting a portion of the unbalance current flowing in said one path, two equivalent thermistors each having a heater the temperature of which varies in accordance with the current flowing through it, and a variable impedance element the value of which is determined by the temperature of the heater, the variable impedance element of one of said thermistors being connected in each of two opposing arms of a Wheatstone bridge circuit, and a second switching means synchronized with the first switching means for periodically switching the current output of said diverting circuit between the heaters of the two thermistors, said bridge circuit being balanced when the temperatures of the two heaters are equal and unbalanced when the temperatures thereof are unequal, said adjusting means being responsive to an unbalance of the bridge circuit in one direction to increase the impedance of said network and being responsive to an unbalance of the bridge circuit in the other direction to decrease the impedance of said network.

7. The combination of claim 2, in which said measuring means, comprises a Wheatstone bridge circuit having two opposing variable impedance arms the values of each of which are determined by the amount of current supplied thereto, a second switching means synchronized with the first switching means for supplying a portion of the unbalance current appearing in said one path during the time intervals in which the effective impedance value of said network is changed by said first switching means to one of said variable impedance arms and a portion of the unbalance current appearing in said one path during the intermediate time intervals to the other variable impedance arm, said bridge circuit being balanced when the impedance values of the two variable impedance arms are equal and unbalanced in one direction or the other when they are unequal depending on which arm has the greater impedance, and said means for adjusting the impedance of said network is responsive to unbalance of the bridge in one direction to increase the impedance of the network and to unbalance of the bridge in the opposite direction to decrease the impedance of said network.

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