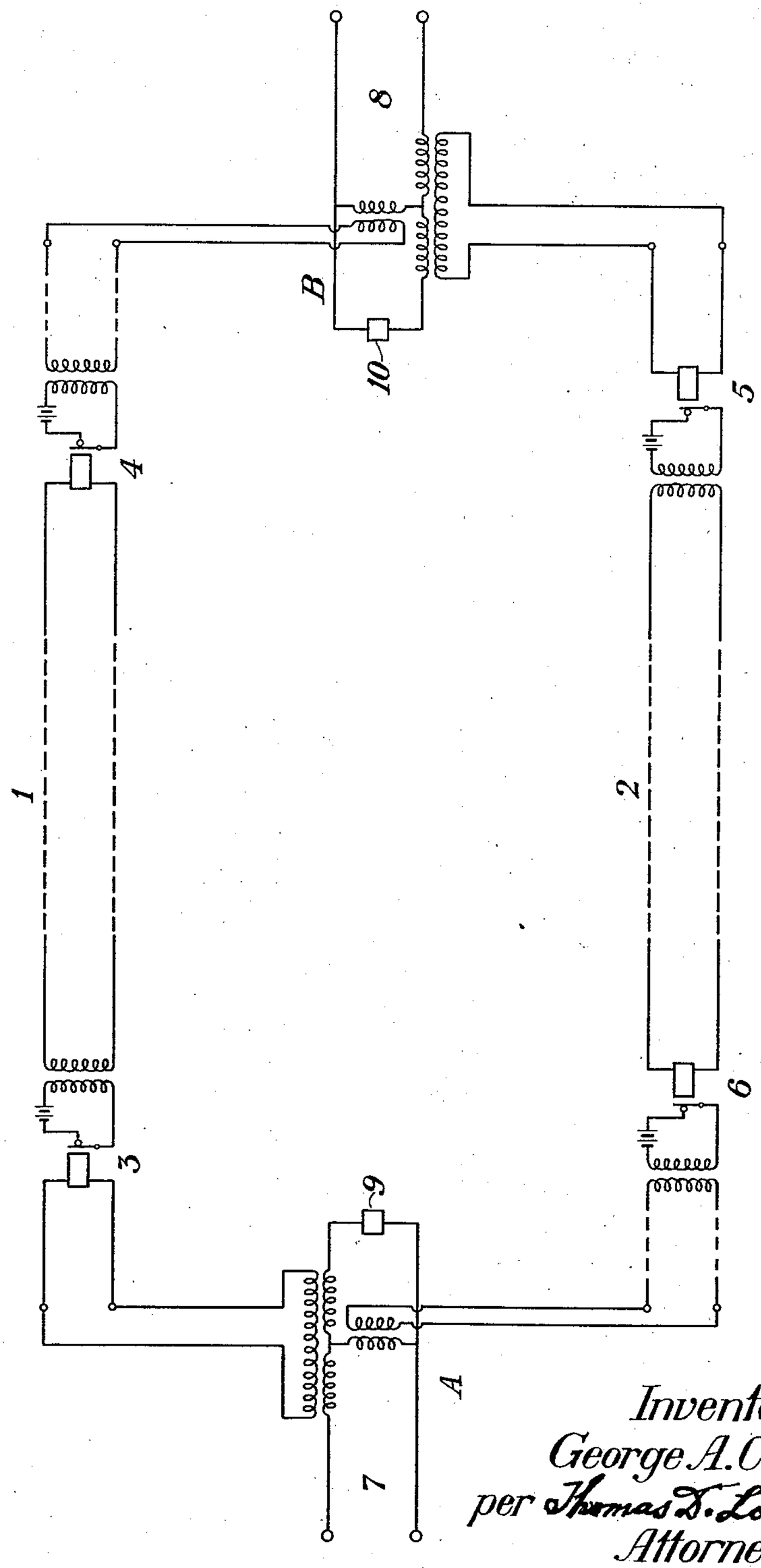
G. A. CAMPBELL.

FOUR-WIRE TRANSMISSION SYSTEM.

APPLICATION FILED JAN. 17, 1916.

1,352,786. Patented Sept. 14, 1920.



Inventor:
George A. Campbell
per Thomas D. Lockwood
Attorney.

UNITED STATES PATENT OFFICE.

GEORGE A. CAMPBELL, OF MONTCLAIR, NEW JERSEY, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

FOUR-WIRE TRANSMISSION SYSTEM.

1,352,786. Specification of Letters Patent. Patented Sept. 14, 1920.

Application filed January 17, 1916. Serial No. 72,606.

To all whom it may concern:

Be it known that I, GEORGE A. CAMPBELL, residing at Montclair, in the county of Essex and State of New Jersey, have invented certain Improvements in Four-Wire Transmission System, of which the following is a specification.

This invention relates to a telephone transmission system and more particularly to a telephone transmission system in which repeaters or amplifiers are employed. One object of the invention is to provide a more effective and more economical circuit and one in which with a given grade of conductor a higher amplification and consequently greater volume of received speech may be secured than is possible in arrangements known to the art without reaching the unstable condition known as "singing." Another object of the invention is to provide a circuit in which a higher amplification may be secured without reaching a condition which impairs intelligibility. These objects of my invention are attained by providing two separate transmission lines, one of which transmits telephonic waves in one direction only, and the other of which transmits in the opposite direction only, and in relating said lines to common terminal stations for two-way communication.

Other and further objects of the invention may be understood by reference to the following description when read in connection with the accompanying drawing which is a diagram illustrating the transmission system of my invention. Referring to the drawing 1 and 2 are separate transmission lines constituting a four-wire transmission system. Line 1 includes a plurality of one-way repeaters, 3, 4, which amplify telephonic waves propagated from left to right. Line 2 includes a plurality of repeaters 5, 6 which amplify telephonic waves from right to left. Line 1 therefore transmits in one direction only while line 2 transmits in the opposite direction only. For convenience mechanical repeaters are shown in the drawing but it will be understood that any type of telephonic repeater may be employed. At station A lines 1 and 2 are coupled to line 7 while at station B lines 1 and 2 are coupled to line 8. Lines 7 and 8 may terminate in central offices or in subscribers' stations. The arrangements whereby the four-wire system is coupled to the terminating lines 7 and 8 are well known to the art. 9 represents a balancing network or artificial line designed to have an impedance equal to that of line 7 while the impedance of artificial line 10 is designed to be equal to that of line 8. When these conditions are satisfied impulses entering line 7 from line 2 do not affect line 1. Similarly impulses entering line 8 from line 1 do not affect line 2. In practice, of course, a perfect balance between the terminating lines and these associated artificial lines is impossible to obtain and maintain. As a consequence there is always a tendency for impulses originating in either of the terminating lines to be repeated around the circuit consisting of lines 1 and 2. When the unbalance reaches a certain value, said value being conditioned by the amplifying power of the repeaters, a condition known to the art as "singing" is established. This tendency to "sing" is inherent in all repeater systems and seriously limits the amount of amplification possible.

Thus, in the ordinary two-way two-repeater systems, the ratio of the repeated or amplified current in one line section, to the originating current in the other line section, is limited by the inherent and unavoidable imperfection of balance, and an excess of amplification sets up singing in the local repeater circuit. In the four-wire system of my invention, however, the amount of amplification possible increases with the length of the four-wire line and the characteristic attenuation thereof, since the tendency to sing over a circuit including the transmission lines 1 and 2 in series, due to an increase in amplification, is neutralized by the corresponding increase in the total attenuation of said lines as the length of the lines is increased. Therefore, the conditions of balance remaining the same, so long as the total attenuation of the pair of lines exceeds the increase of amplification of the repeaters, the system cannot sing. For instance, if stations A and B be brought together so that lines 1 and 2 are quite short, as is the case in the ordinary two-way two-repeater system, it is possible to adjust the amplifiers so that the current leaving the system over outgoing line 8 is equal to, or somewhat greater than the current entering the system from line 7, without any resultant singing. If now, stations A and B be separated any distance no matter how great,

the conditions of balance remaining the same, the amplification may be increased until substantially the same current leaves the system over line 8 as before, and no singing will result, since the increase in amplification tending to cause singing is balanced by a corresponding increase in attenuation due to the increased length of lines 1 and 2. It will thus be seen that however widely stations A and B may be separated geographically, they may be brought together electrically, and in fact, the amplification can be adjusted so as to secure a gain in transmission at station B as compared with station A, without any singing taking place.

In other words the system is so arranged that the amplification of the one-way repeaters in the two transmission lines comprising the four-wire circuit shall not exceed the loss due to the attenuation of said lines by an amount greater than the loss due to the means for balancing the terminating arrangements. With the system thus adjusted, a wave impressed upon one of the lines and transmitted over a closed circuit including said transmission lines and interconnecting means, will arrive at the originating point decreased in amplitude, so that singing will not take place.

The advantages attending the four-wire system of transmission, disclosed above, are many and important. In ordinary transmission systems employing repeaters, the amount of amplification possible is strictly limited as heretofore stated, by the fact that the balancing network can only be at best imperfect and that therefore there is always more or less interaction between the input and output side of a repeater, said interaction giving rise to the condition of sustained interaction known as singing. As a consequence the amplification is limited by the degree of said unbalance. In the four-wire system very high amplification is possible without singing; in fact theoretically with a single repeater an amplification is possible without singing which entirely neutralizes the current diminution consequent upon the line attenuation, irrespective of the length of the line. Further if repeaters are operated in tandem on an ordinary two-wire system interaction between repeaters limits the amplification of each repeater and necessitates a definite separation between repeater stations. In the four-wire system this limitation is entirely absent. In the four-wire system also balancing networks are required only at the two terminals of the four-wire lines whereas in the two-wire system balancing networks or their equivalents are required at each repeater station. In many systems wherein high quality and large volume of received speech signal is desired, the above-mentioned advantages more than compensate for the duplication of line required by the four-wire transmission system. In other four wire systems it is possible because of the advantages above pointed out, to use low grade conductors for the two transmission lines of the four wire system, so that the cost of such conductors, together with that of amplifiers worked at high amplification, is less than the cost of a two wire system using high grade conductors with repeaters worked at low amplification.

While the invention has been illustrated as embodied in a certain form it will be understood that various changes may be made in the embodiment without departing from the spirit of the appended claims.

I claim:—

1. A transmission system comprising two stations, two transmission lines connecting said stations for transmission in opposite directions, means at said stations interconnecting the ends of said lines, said means being so arranged that the transmission from one line to the other is relatively small, and one-way repeaters in said transmission lines, the total transmission loss over the circuit comprising said transmission lines and interconnecting means being at least equal to the amplification due to the repeaters.

2. A telephone transmission system comprising two stations, two separate transmission lines connecting said stations; a one-way repeater in one of said transmission lines, said repeater amplifying and transmitting impulses in one direction only; a one-way repeater in the other of said transmission lines amplifying and transmitting impulses in the opposite direction only, and means at said stations interconnecting the ends of said lines, said means being so arranged that the transmission from one line to the other is relatively small, the total transmission loss over the circuit comprising said transmission lines and interconnecting means, being at least equal to the amplification due to the repeaters.

3. A four-wire transmission system comprising two stations, terminating lines at said stations, two separate transmission lines connecting said terminating lines, one-way repeaters in one of said transmission lines repeating in one direction, one-way repeaters in the other of said transmission lines repeating in the other direction, and means interconnecting the ends of said transmission lines with said terminating lines, said means being so arranged that the transmission from one of said transmission lines to the other will be relatively small, the total transmission loss over the circuit comprising said transmission lines and interconnecting means being at least equal to the amplification due to the repeaters.

4. A telephone transmission system com-

prising two separate transmission lines, one of said transmission lines transmitting telephonic impulses in one direction only, and the other of said transmission lines transmitting telephonic impulses in the opposite direction only; a plurality of one-way repeaters in each of said transmission lines, and means interconnecting the ends of said lines, said means being so arranged that the transmission from one line to the other is relatively small, the total transmission loss over the circuit comprising said transmission lines and interconnecting means being at least equal to the amplification due to the repeaters.

5. A transmission system comprising two stations each having an input circuit and an output circuit, two transmission lines connecting said stations, the input circuit of one of said stations being connected to one of said transmission lines and its output circuit being connected to the other of said transmission lines, the input circuit of the other station being connected to the second of said transmission lines and its output circuit being connected to the first of said transmission lines whereby one of said transmission lines transmits in one direction and the other of said transmission lines transmits in the opposite direction, a one-way repeater in each of said transmission lines, and means interconnecting the input and output circuit of each station, said means being so arranged that the transmission from one line to the other is relatively small, the total transmission loss including the said transmission lines, input and output circuits, and interconnecting means, being at least equal to the amplification due to the repeaters.

6. In a telephone system, the combination of two separate transmission lines constituting a four-wire transmission system extending between two stations, terminating lines at each of said stations associated with the ends of said four-wire transmission system, artificial lines at said station for balancing each of said terminating lines, and amplifying means in each of said transmission lines so adjusted that the amplification of said amplifying means shall not exceed the attenuation of said transmission lines by an amount greater than the loss due to said balancing means.

7. In a telephone system, two stations, a four-wire transmission circuit extending between said stations comprising two transmission paths, terminating lines at each station, means for associating said terminating lines with said four-wire circuit, said means being so arranged that the transmission from one path to the other is relatively small, and means to amplify the current transmitted from said connecting lines to said four-wire circuit, the total transmission loss over the four-wire circuit and said inductive associating means being at least equal to the amplification due to the amplifying means.

8. A transmission system comprising two stations, two transmission lines connecting said stations for transmission in opposite directions, terminating arrangements at said stations to which the ends of said lines are connected, balancing means for said terminating arrangements and amplifiers in said lines so adjusted that the amplification of said amplifiers shall not exceed the attenuation of said lines by an amount greater than the loss due to said balancing means.

9. A transmission system comprising two stations, terminating lines at said stations, balancing means for said terminating lines, two transmission lines connecting said stations for transmission in opposite directions, means to associate the ends of said transmission lines with said terminating lines and balancing means and amplifiers for said transmission lines so adjusted that the amplification of said amplifiers shall not exceed the attenuation of said transmission lines by an amount greater than the loss due to the means for associating the ends of said transmission lines with the terminating lines and balancing means.

10. A transmission system comprising two stations, two transmission lines connecting said stations for transmission in opposite directions, means at said stations interconnecting the ends of said lines, said means being so arranged that the transmission from one line to the other is relatively small, and one-way repeaters in said lines, the amplification of the repeaters and the attenuation of said lines being such that a wave impressed upon one of said lines and transmitted over a closed circuit, including said transmission lines and interconnecting means, will arrive at the originating point decreased in amplitude.

11. A transmission system comprising two stations, two transmission lines connecting said stations for transmission in opposite directions, terminating arrangements for said transmission lines at said stations, balancing means for said terminating arrangements and one-way repeaters in said lines, the amplification of the repeaters and the attenuation of said lines being such that a wave impressed upon one of said lines and transmitted over a closed circuit, including said transmission lines, will arrive at the originating point decreased in amplitude.

12. A transmission system comprising two stations, terminating lines at said stations, balancing means for the terminating lines, two transmission lines connecting said stations for transmission in opposite direc-

tions, means at said stations interconnecting the ends of said transmission lines with said terminating lines and balancing means and one-way repeaters in said transmission lines, the amplification of the repeaters and the attenuation of said transmission lines being such that a wav impressed upon one of said transmission lines and transmitted over a closed circuit, including said transmission lines and interconnecting means, will arrive at the originating point decreased in amplitude.

In testimony whereof, I have signed my name to this specification in the presence of two subscribing witnesses, this thirteenth day of January, 1916.

GEORGE A. CAMPBELL.

Witnesses:

FRED'K S. ROBINSON,

RALPH W. WOLF.