Jan. 15, 1924. **1,480,612**

H. W. HITCHCOCK

MULTIPLEX SINALING SYSTEM

Filed Nov. 12, 1921

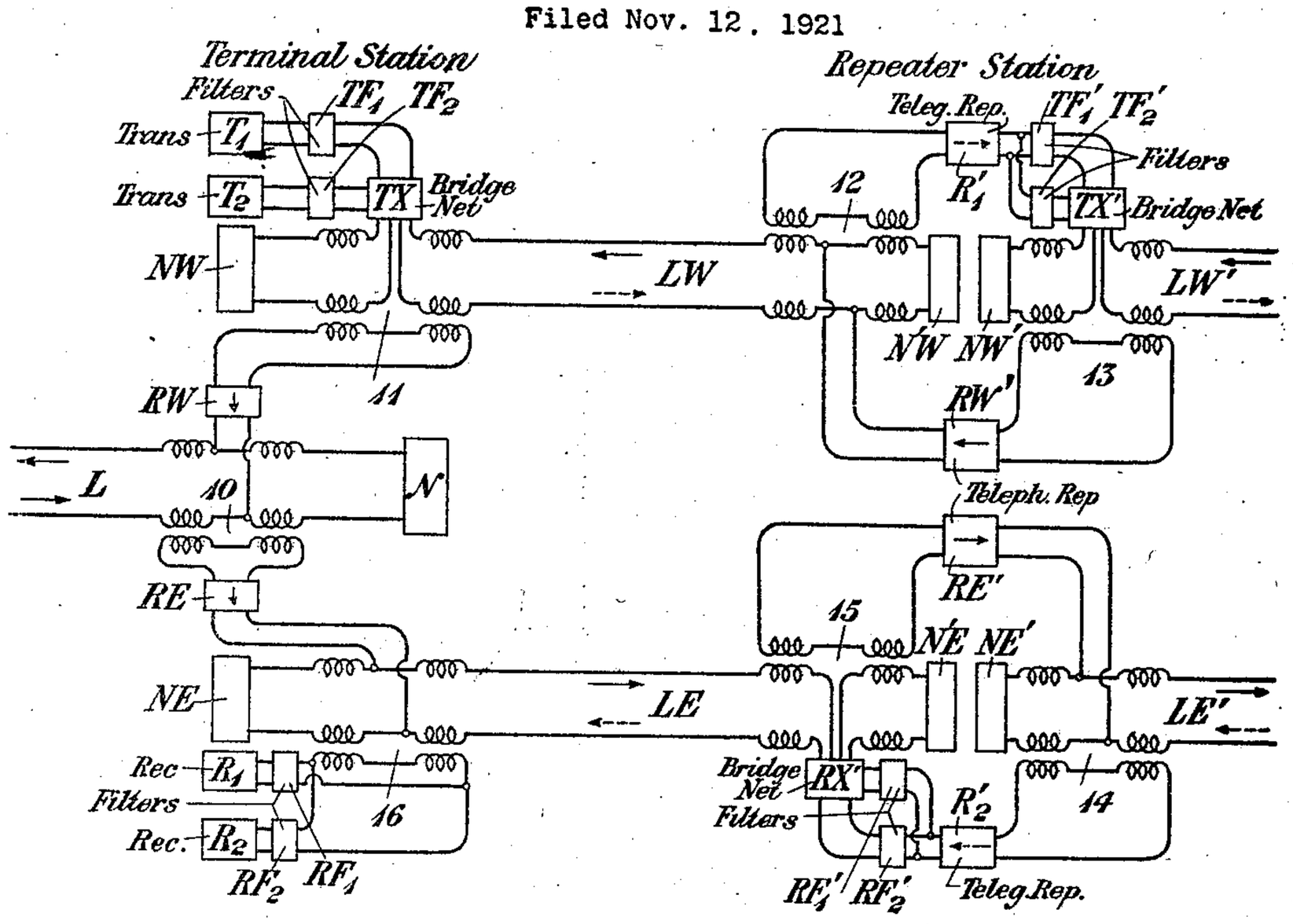

Fig. 1

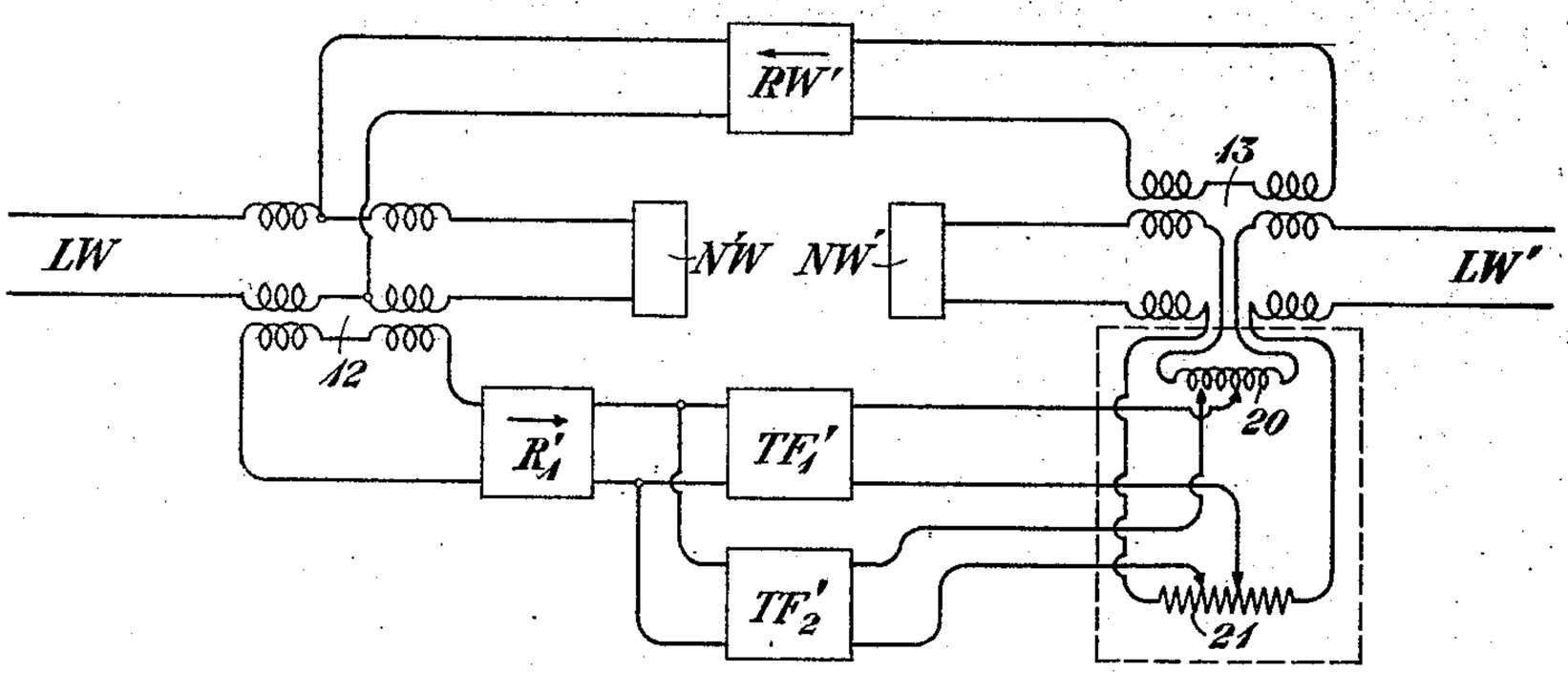

Fig. 2

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UNITED STATES PATENT OFFICE.

HARRY W. HITCHCOCK, OF NEW YORK, N. Y., ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

MULTIPLEX SIGNALING SYSTEM.

Application filed November 12, 1921. Serial No. 514,736.

To all whom it may concern:

Be it known that I, HARRY W. HITCHCOCK, residing at New York, in the county of Bronx and State of New York, have invented certain Improvements in Multiplex Signaling Systems, of which the following is a specification.

This invention relates to transmission circuits and more particularly to telephone circuits upon which carrier channels may be superposed.

One of the objects of the invention is to simultaneously transmit ordinary voice frequencies and one or more carrier frequencies within the voice range over the same circuit, said carrier frequencies being adapted for the transmission of telegraph signals. This object of the invention, as well as other objects, may be accomplished by utilizing a transmission circuit of the four-wire type, over each pair of wires of which the telephone frequencies are transmitted in one direction, and the carrier frequencies employed for telegraph transmission are transmitted in the opposite direction, suitable balancing arrangements being provided to discriminate between the oppositely directed transmissions.

The invention may be more fully understood from the following description when read in connection with the accompanying drawing, Figure 1 of which illustrates a circuit arrangement embodying the principles of the invention, and Fig. 2 of which illustrates a balancing arrangement used in connection with the circuit of Fig. 1.

Referring to Fig. 1, L is a terminal telephone line adapted to be associated with a four-wire circuit through a hybrid coil 10, and a balancing network N. The four-wire circuit comprises two pairs of wires, each pair being divided in sections at repeater points so that sections such as LW and LW′ may be used for transmitting voice frequencies from east to west, while sections such as LE and LE′ may be used for transmitting voice frequencies from west to east. At the terminal point the section LW, instead of being connected to the terminal line L by a direct bridge across neutral points of the transformer 10, is terminated in a hybrid coil 11 and balancing network NW. The third winding of the hybrid coil is connected to the neutral points of the hybrid coil 10 through a one-way telephone amplifier RW. The hybrid coil 11 is utilized for the purpose of connecting the carrier transmitter circuits with the line section LW for transmission from west to east. T_1 and T_2 designate conventionally indicated carrier telegraph transmitters which are connected to a common bridged network TX, associated with the hybrid coil through selecting filters TF_1 and TF_2. The bridged network TX is provided for the purpose of securing an accurate balance between the line section LW and the network NW at the carrier frequencies, and the details of this network are illustrated in Fig. 2, which will be described later. The filters TF_1 and TF_2 may be ordinary tuned circuits or band filters of the Campbell type.

At the repeater point the one-way repeater RW′ for the telephone circuit, instead of being connected directly in the line, as is the usual practice with four-wire circuits, is connected between the line sections LW and LW′ through two hybrid coil arrangements 12 and 13, the input side of the repeater being connected to neutral points of the main windings of the hybrid coil 12. The line sections LW and LW′ are balanced by networks N′W and NW′. This arrangement permits of transmission of telephone currents from east to west, although the introduction of the hybrid coils, 11, 12 and 13 with the associated balancing networks, involve some transmission loss. This loss may be made up, however, by working the repeaters at a higher gain.

In order that telegraph signals may be transmitted from west to east over the line sections LW and LW′, these sections are interconnected through a telegraph repeater R_1', which may be, for example, a vacuum tube repeater adapted to amplify all of the carrier channels simultaneously. The output circuit of the repeater is divided so that the channels are separated through filters TF_1' and TF_2', the channels then being joined to the hybrid coil 13 through the bridged network TX′, which will be described later.

The line sections LE and LE′ are connected for transmission of the telephone currents from west to east in a similar manner, hybrid coils 14 and 15 with associated balancing networks N′E and NE′ being

provided, and the telephone repeater RE′ being connected to these hybrid coils in a manner analogous to that already described, but with the connections reversed so that transmission will take place in the opposite direction. Likewise, the carrier channels may be transmitted from east to west through a telegraph repeater R_2', having selecting devices RF_1', RF_2', in its output circuit for segregating the channels, the channels being again combined through the network RX′ associated with the neutral points of the hybrid coil 15.

At the terminal station the line section LE terminates in the hybrid coil 16 and balancing network NE, and carrier telegraph receivers R_1 and R_2 are associated with the third winding of the hybrid coil 16 through filters RF_1 and RF_2. The terminal line L is associated with line section LE through a one-way amplifier RE, whose output side is connected to neutral points of the hybrid coil 16, and whose input side is associated with the third winding of the hybrid coil 10.

Voice currents incoming from the line L will be transmitted through the hybrid coil 10 and amplifier RE to the midpoints of the hybrid coil 16, and thence over the line section LE to the hybrid coil 15. The voice currents applied to the neutral points of hybrid coil 16 do not react upon the telegraph receivers R_1 and R_2 because of the balanced condition of the circuit at this point. At the repeating station the voice currents transmitted east pass through the hybrid coil 15 to the telephone repeater RE′. The amplified currents are then impressed upon neutral points of the hybrid coil 14 for transmission to the line section LE′. The circuit being balanced at this point prevents the transmission of the voice currents into the circuit including the telegraph repeater R_2'. Telephone currents transmitted from the line section LW′ in a similar manner pass through the transformer 13, amplifier RW′ and hybrid coil 12 to the line section LW without reacting in the telegraph repeater R_1'. Telephone currents transmitted over the line section LW pass through the hybrid coil 11 and amplifier RW to midpoints of the hybrid coil 10 and thence to the terminal line L. Owing to the balanced condition of the circuit at the hybrid coil 10, the telephone currents transmitted from east to west do not react in the circuit LE—LE′.

The carrier frequencies produced by the transmitters T_1 and T_2 are impressed upon neutral points of the hybrid coil 11 and are therefore prevented from passing through the amplifier RW, but flow over the circuit LW from west to east in a direction opposite to that of the telephone currents. At the repeater station the telegraph carrier frequencies pass through the hybrid coil 12 to the telegraph repeater R_1' and upon being impressed upon neutral points of the hybrid coil 13 are transmitted over the line LW′ from west to east. These currents are prevented from entering the circuit of the telephone repeater RW′ owing to the balanced condition of the hybrid coil 13. Similarly, telegraph carrier frequencies within the voice range incoming from the line section LE′ pass through the hybrid coil 14 and telegraph repeater R_2' to midpoints of the hybrid coil 15, and thence to the line section LE without reacting in the telephone repeater RE′. These currents are transmitted over the line section LE from east to west, and pass through the hybrid coil 16 to the selective circuits RF_1 and RF_2, which select the individual carrier frequencies into the proper channels so that they are received by the receivers R_1 and R_2.

The balancing circuits N, NW, N′W, NW′, etc., are designed to give as high a degree of balance as possible over the entire operating range and in addition to be balanced exactly for the telegraph currents. The filters such as TF_1, TF_2, TF_1', TF_2', and the corresponding filters used for transmission in the opposite direction, are designed to transmit only currents of the carrier frequency assigned to each channel, and consequently, the circuit of the telegraph repeater is selective of the carrier frequencies. The combination of selective circuits associated with the amplifier and balancing network results in a very high singing point for all frequencies and a low crosstalk between the telephone and telegraph systems.

Various arrangements will suggest themselves whereby the networks may be balanced exactly for the telegraph frequencies. One arrangement well adapted for the purpose is illustrated in Fig. 2, which shows in more detail the repeating apparatus for interconnecting two line sections of one side of the four-wire circuit. The exact balance in this case is attained by inserting between the two halves of the hybrid coil 13 a small reactance 20 and a small resistance 21. The bridged points of the hybrid coil are so arranged that they can be connected to the reactance and resistance at any point. In this way, resistance or reactance may be introduced into either the line or network side of the hybrid coil by changing the position of the contacts. The resistance and reactance need only be as large as the greatest difference in impedance between the line and network which it is desired to balance. Since a set of bridged points may be connected to a selective circuit having a high impedance to every frequency except the one for which it is to be used, it is possible to balance two or more circuits on the same hybrid coil as

indicated in the drawing, the circuits being rendered selective by means of the filters TF_1', TF_2'. Since the circuit including the filter TF_2' has a high impedance with respect to the currents which are transmitted through the filters TF_1', the position of the contacts associated with the filter TF_2' will have a very small effect upon the balance so far as the currents transmitted through TF_1' are concerned. By one or two adjustments of these contacts it is possible, therefore, to balance both circuits very closely.

The arrows on the amplifiers RW' and R_1' in figure may be taken to show that transmission takes place in the direction indicated. Under these conditions the refined balancing arrangement prevents telegraph carrier frequencies from reacting in the telephone circuit. If the one way amplifier be arranged to transmit in the opposite direction, however, the balancing arrangement becomes effective to prevent telephone frequencies which coincide with the telegraph carrier frequencies from producing any reactance in the telegraph circuit.

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 multiplex transmission system, a four-wire circuit comprising two lines, over one of which telephone currents are transmitted in one direction and over the other of which telephone currents are transmitted in the other direction, and means whereby signaling currents within the voice range may be transmitted over each of said lines in a direction opposite that to which the voice currents are transmitted.

2. In a multiplex transmission system, a four-wire circuit comprising two lines, over one of which telephone currents are transmitted in one direction and over the other of which telephone currents are transmitted in the other direction, means whereby signaling currents within the voice range may be transmitted over each of said lines in a direction opposite to that in which the voice currents are transmitted, and means at terminal points of said lines for separating said signaling currents from said voice currents.

3. In a multiplex transmission system, a four-wire circuit comprising two lines, over one of which telephone currents are transmitted in one direction and over the other of which telephone currents are transmitted in the other direction, means whereby signaling currents within the voice range may be transmitted over each of said lines in a direction opposite that to which the voice currents are transmitted, and means at terminal points of said lines for separating said signaling currents from said voice currents, said means comprising balanced circuit arrangements.

4. In a multiplex transmission system, a four-wire circuit comprising a pair of lines over one of which voice currents are transmitted in one direction and over the other of which voice currents are transmitted in the opposite direction, repeaters in each of said lines for amplifying voice currents, means associated with said lines whereby signaling currents within the voice range may be transmitted over said lines in directions opposite to those in which voice currents are transmitted, and means at said repeater points for separating said voice currents and said signaling curents.

5. In a multiplex transmission system, a four-wire circuit comprising a pair of lines over one of which voice frequencies are transmitted in one direction and over the other of which voice currents are transmitted in the opposite direction, repeaters in each of said lines for amplifying voice currents, means associated with said lines whereby signaling currents within the voice range may be transmitted over said lines in directions opposite to those in which voice currents are transmitted, and means at said repeater points for separating said voice currents and said signaling currents, said means comprising balanced circuit arrangements.

6. In a multiplex signaling system, a four-wire circuit comprising a pair of lines over one of which voice currents may be transmitted in one direction and over the other of which voice currents may be transmitted in the opposite direction, terminal circuits with which said lines are associated, transmitting arrangements and receiving arrangements associated with each line at the terminal points for transmitting signaling currents within the voice range over said lines in directions opposite to the directions in which voice currents are transmitted, a hybrid coil and a balancing network associated with each line at the terminal thereof, connections from said hybrid coils to said terminal circuits and connections from said transmitting and receiving arrangements to said hybrid coils, said connections being conjugate with respect to the connections to the terminal circuit.

7. In a multiplex signaling system, a four-wire circuit comprising a pair of lines over one of which voice currents may be transmitted in one direction and over the other of which voice currents may be transmitted in another direction, means associated with said lines for transmitting signaling currents within the voice range over said lines in directions opposite to the directions in which voice currents are transmitted, repeater stations associated with said lines, an amplifier

for voice currents and an amplifier for signaling currents at each repeater station, hybrid coils and balancing networks associated with said lines at said repeater stations, and connections from each of said hybrid coils to said amplifiers, said connections being so arranged that the connection to the voice amplifier will be conjugate with respect to the connection to the signaling current amplifier.

8. An arrangement for discriminating between the oppositely directed transmissions comprising a transmission line, a balancing network for approximately balancing said transmission line over a range of frequencies, a hybrid coil interposed between said transmission line and balancing circuit, a one-way circuit inductively associated with said line through said hybrid coil, an inductance and a resistance interconnected between the two halves of the hybrid coil, and a plurality of signaling circuits bridged across said inductance and resistance elements at points such that a condition of conjugacy will exist between each of said circuits and said one-way circuit at the frequency used for transmitting over each of said circuits.

In testimony whereof, I have signed my name to this specification this 5th day of November, 1921.

HARRY W. HITCHCOCK.