Nov. 23 , 1926. 1,607,687

H. NYQUIST

ELECTRICAL CIRCUITS

Filed Sept. 6, 1924

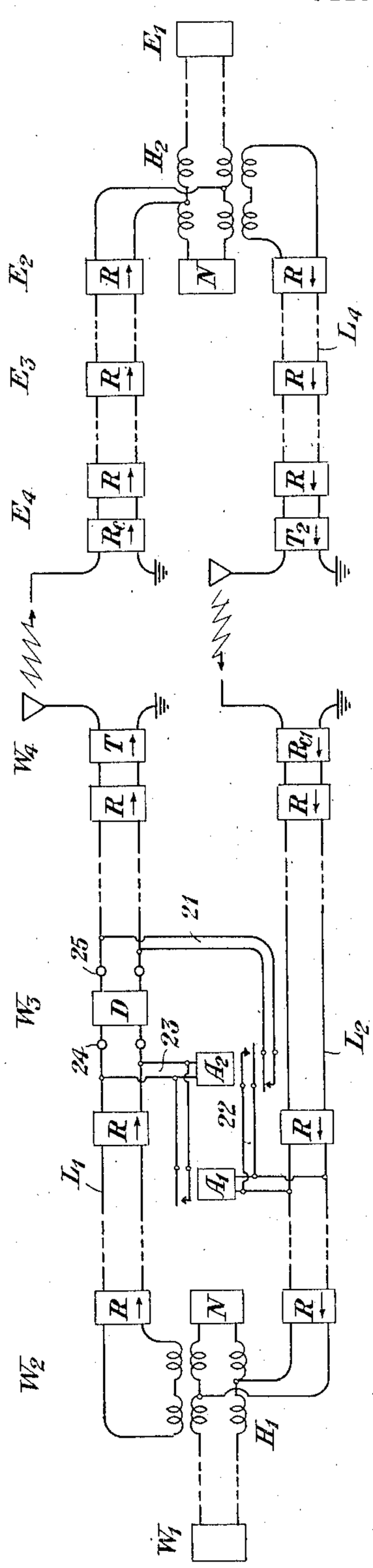

Fig. 1

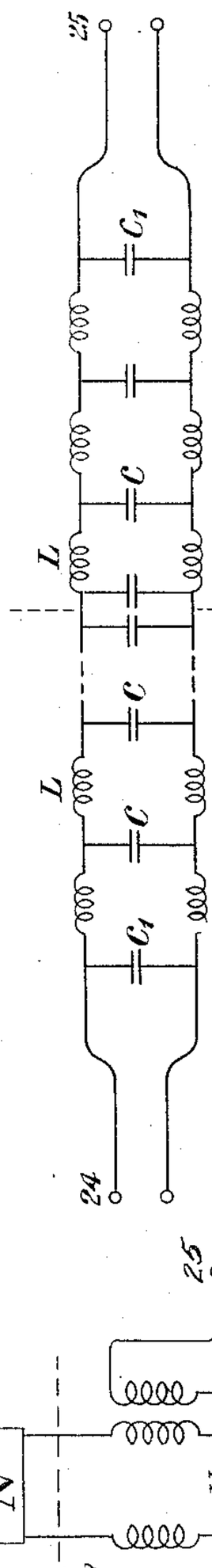

Fig. 2

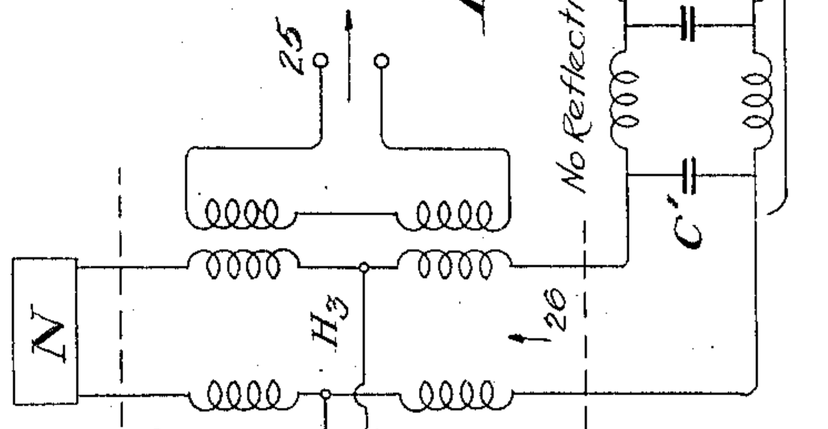

Fig. 3

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UNITED STATES PATENT OFFICE.

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ELECTRICAL CIRCUITS.

Application filed September 6, 1924. Serial No. 736,378.

The object of my invention is to provide a new and improved method for economizing in the use of apparatus to produce desired changes in electric currents. Another object of my invention is to provide apparatus for modifying an electric current in a desired manner with effective use of the elements of the apparatus. Another object of my invention relates to reducing the amount of apparatus in an electrical network by employing reflection and utilizing the same network for transmission two ways. These and various other objects of my invention will become apparent on consideration of a specific example which I have chosen for disclosure in the following specification and claims taken with the accompanying drawings. It will be understood that the following specification relates to this example of the invention, leaving the invention to be defined in the claims.

Referring to the drawings, Figure 1 is a diagram illustrating a two-way wire and wireless transmission system in which my invention finds useful application; Fig. 2 is a diagram of a delay circuit that may be employed in the system of Fig. 1; and Fig. 3 is a diagram of a delay circuit embodying my invention.

In the system shown in Fig. 1, W_1 and E_1 are two telephone stations, each with a transmitter and receiver, and the apparatus lying between these stations is adapted to transmit speech both ways, partly by wire and partly by wireless. The normal condition of the system when not in use involves a closure of the shunt 21 at the back contact of the amplifier-detector unit relay A_2. When E_1 speaks, the transmission is into the hybrid coil H_2 which connects with a four-wire line, as shown. Thence the voice currents go through repeaters R and over the wire line L_4 to the radio transmitter T_2 from which the radio waves are received by the radio receiver Rc_1. Thence transmission is over the line L_2 through the repeaters R to the hybrid coil H_1 and thence to the station W_1.

The transmission, as thus described, is not affected by the shunt 22, because it is open at the front contact of the relay system A_2. The symbol A_1 indicates an amplifier-detector unit relay which is operated by the voice current in the line L_2 and, while the voice currents are being carried from station E_1 to station W_1, the relay A_1 is energized and closes on its front contact the shunt 23, thus inhibiting transmission from W_1 to E_1.

If the subscriber at W_1 speaks while the system is not in use, the voice currents in the primary windings of the hybrid coil H_1 will occasion voice currents in the line L_1 and repeaters R which will go to the amplifier-detector unit relay A_2 and open the shunt 21 and close the shunt 22. The opening of the shunt 21 will make the system operative for transmission from W_1 to E_1, and the closing of the shunt 22 will make it inoperative for transmission the other way.

In order that the transmission from W_1 to E_1 may not be mutilated, the delay circuit D is interposed. This is so arranged that, while the initial voice current waves are passing through D on the way from W_1 to E_1, the relay A_1 will have time to operate so that when these waves reach the output of D the shunt 21 will have been opened, and they will pass in unmutilated condition on over the line L_1 to the transmitting station W_4 and thence in an obvious manner to the subscriber at E_1.

It will be seen that, although the system is a four-wire system, it is so arranged at station W that only one pair is operative at one time. Normally the pair from E_1 to W_1 will be operative in virtue of the normally open condition of the shunt 22, and the pair from W_1 to E_1 will be inoperative because of the closure of the shunt 21. When E_1 talks, then as long as he talks continuously he sustains this condition by virtue of the energization of relay A_1 which closes the shunt 23 and prevents energizing relay A_2 which would close the shunt 22. W_1 can get possession of the line only when E_1 is not talking and when, accordingly, the relay A_1 is not energized. Then when W_1 talks, the relay A_2 is energized thus opening the shunt 21 and closing the shunt 22 thereby preventing energization of relay A_1 and preventing the closure of the shunt 23, and this condition maintains as long as W_1 talks continuously.

In this way interference, due to echoes or singing around the four-wire circuit, is prevented.

A delay circuit such as indicated by the character D in Fig. 1 is shown more in detail

in Fig. 2. It consists of a large number of series coils L and alternately disposed shunt condensers C, the terminal condensers having appropriate capacity values differing from the others as indicated by the character C_1. To get the necessary delay, the number of sections in the network of Fig. 2 may need be as great as several hundred.

To reduce the quantity of apparatus involved, I construct the network D in accordance with Fig. 3, instead of Fig. 2. The voice currents coming in from the left to the terminals 24 divide equally, half going to the network N and half to the network D' so that there is a balance in the secondary winding of the hybrid coil H_3 and, as described thus far, there is no current to the output terminals 25.

The network N is designed so that there is no reflection of the current passing into it, and its energy is entirely absorbed therein. It is designed to balance a network extending to infinity whose sections are like those of network D'. The network D' consists of sections like the sections of Fig. 2 except that there are only half as many. The current wave entering the network D' from the left traverses it to the right and is there reflected and goes back entering the hybrid coil, as indicated by the arrow 26. Its energy is divided, partly going out at the normal input terminals 24 and partly at the normal output terminals 25.

While there is no reflection between the hybrid coil and the network D' for currents entering the network D' at this place, there is complete reflection at the extreme unconnected end of the network D', and thus it will be seen that the network D' is completely traversed twice, and since it has half the number of sections of Fig. 2, the wave passes through the same number of sections as in Fig. 2.

Referring to Fig. 2, if there is an odd number of condensers C and if the middle condenser is replaced by two condensers in parallel, as shown at 27, then it will be seen that if reflection can be accomplished at 27, the completely reflected wave will have traversed the same number of sections and will have been subjected to the same modifying influence as the completely transmitted wave would have been. This is the principle of Fig. 3 as compared with Fig. 2.

While I have explained my invention in relation to a delay circuit, it will readily be understood that its principle will be found applicable for the case of any circuit in which it is desired to make a change in the current at the output terminals as compared with the current at the input terminals.

I claim:

1. The method of producing a desired degree of change in electric wave currents between a pair of input terminals and a pair of output terminals which consists in sending the currents from the input terminals without immediate effect on the output terminals through a network that produces half the desired change, and reflecting the currents back through the said network to complete the desired change, and making the reflected currents effective on the output terminals of the system.

2. In combination, a hybrid coil with output terminals unaffected directly by current introduced at the input terminals and a network to receive current from the input terminals and reflect it back, the system being adapted to make the reflected current waves effective on the output terminals.

3. In combination, a hybrid coil with a pair of input terminals and a pair of output terminals and with an absorbing network and a reflecting network balanced against each other with respect to one said pair of terminals.

4. In combination, a hybrid coil with input and output terminals and two networks to which the input currents divide, one network being completely absorbent and the other reflecting the waves transmitted through it whereby these waves, after twice traversing the last mentioned network, become effective on the output terminals.

5. A delay network comprising a series of sections and two conjugate pairs of terminals at one end thereof, and means to establish the conjugate relation between said two pairs of terminals whereby input currents on one pair give an output on the other pair only by transmission through the said series of sections and reflection back therethrough.

6. The method of delaying electric wave currents in a network having two conjugate pairs of terminals which consists in applying the currents at one pair and delaying them in transmission therethrough, then reflecting them back to cause further delay and putting them out at the other pair of terminals.

In testimony whereof I have signed my name to this specification this 5th day of September, 1924.

HARRY NYQUIST.