May 28, 1929. H. NYQUIST 1,714,567

TELEGRAPH CIRCUIT

Filed Dec. 9, 1927

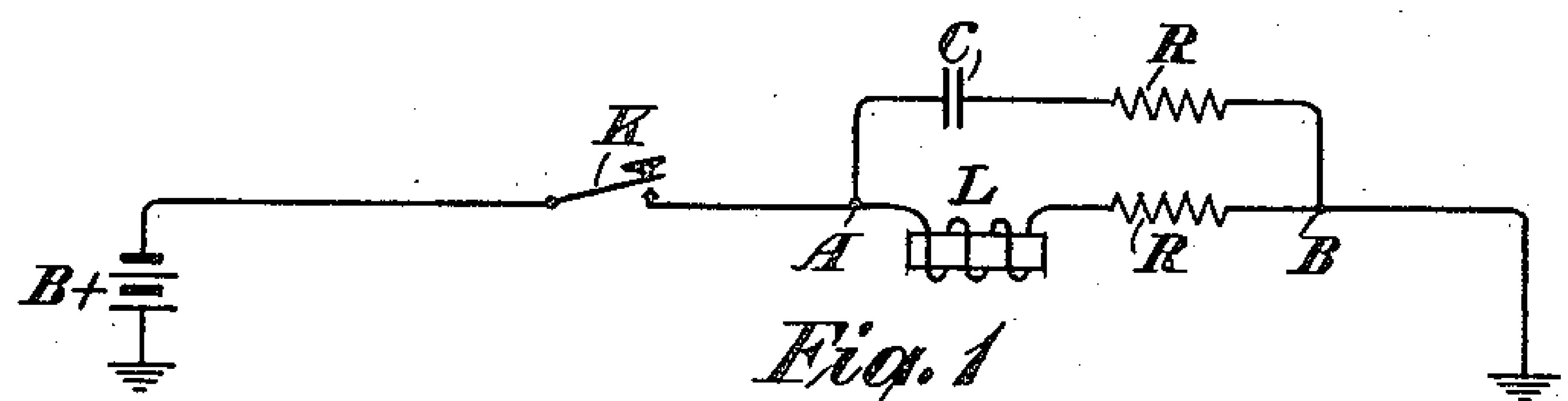

Fig. 1

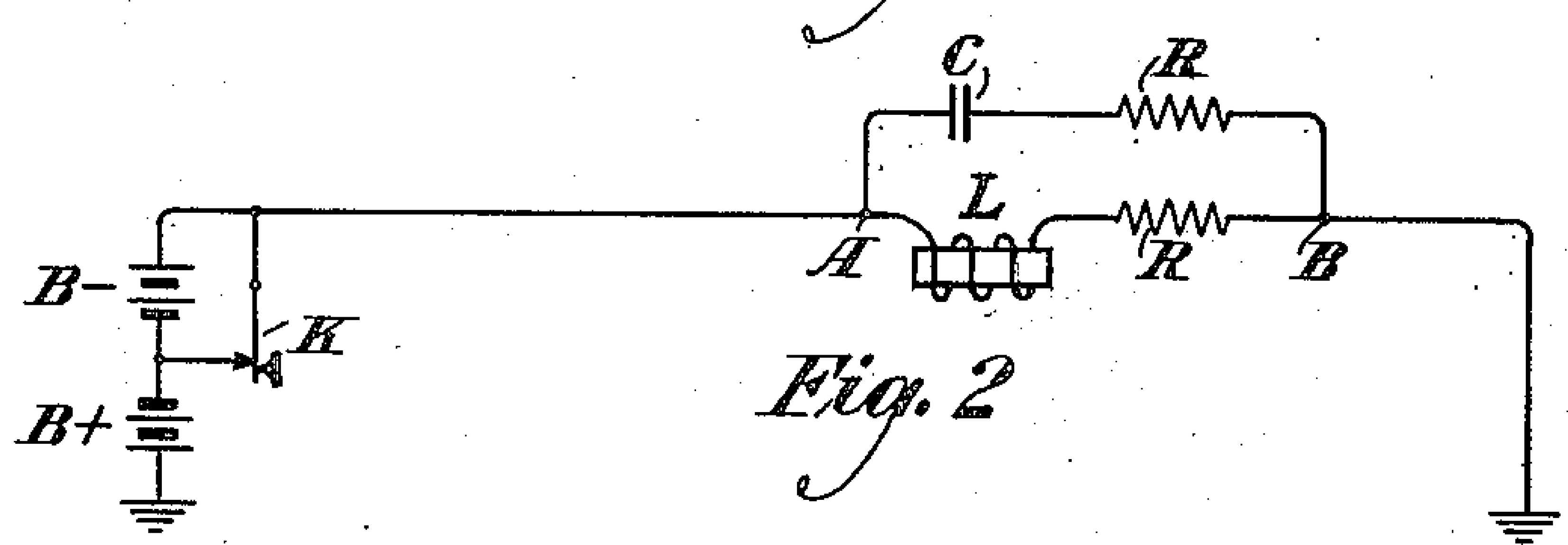

Fig. 2

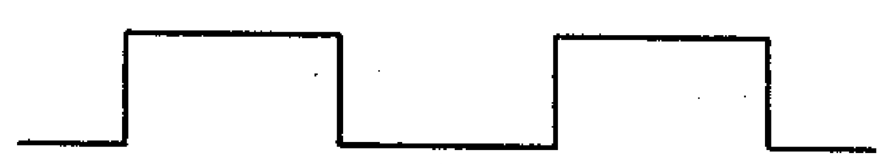

Fig. 3

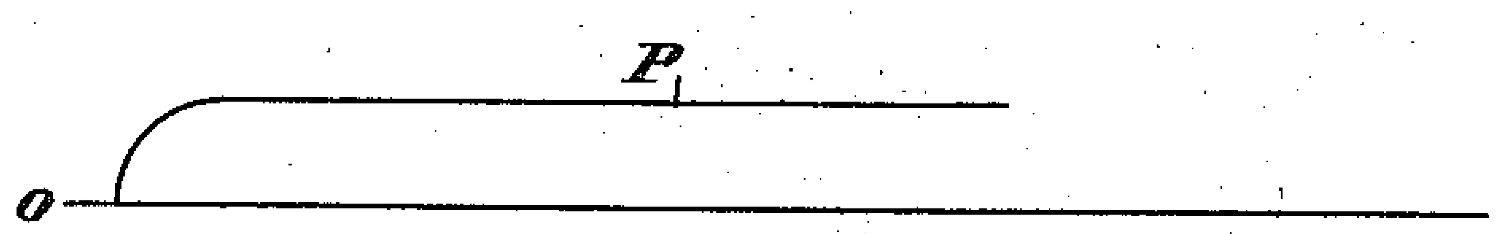

Fig. 4

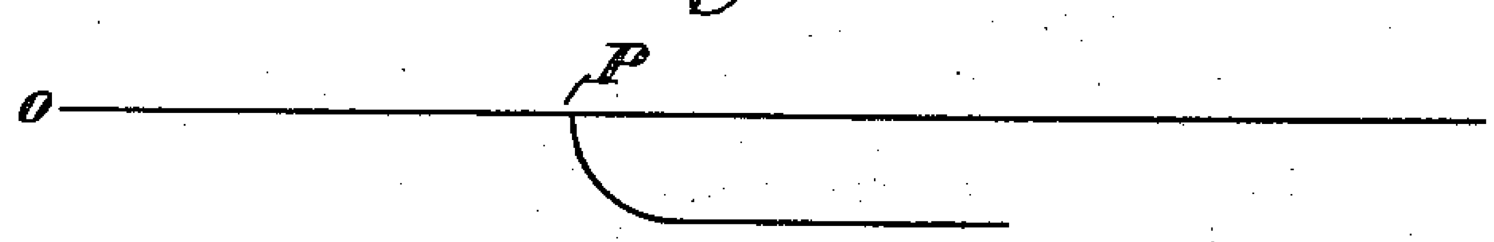

Fig. 5

Fig. 6

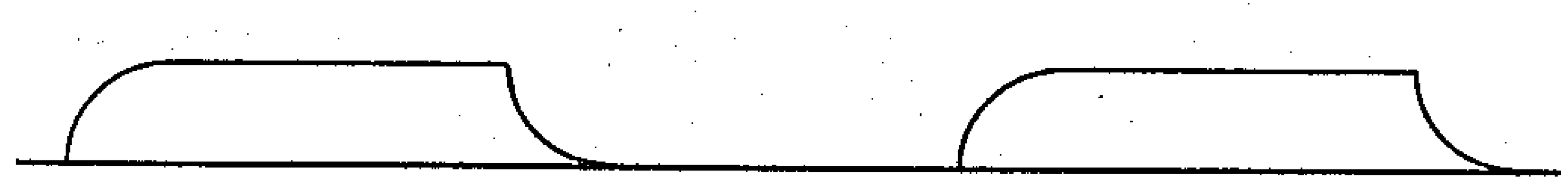

Fig. 7

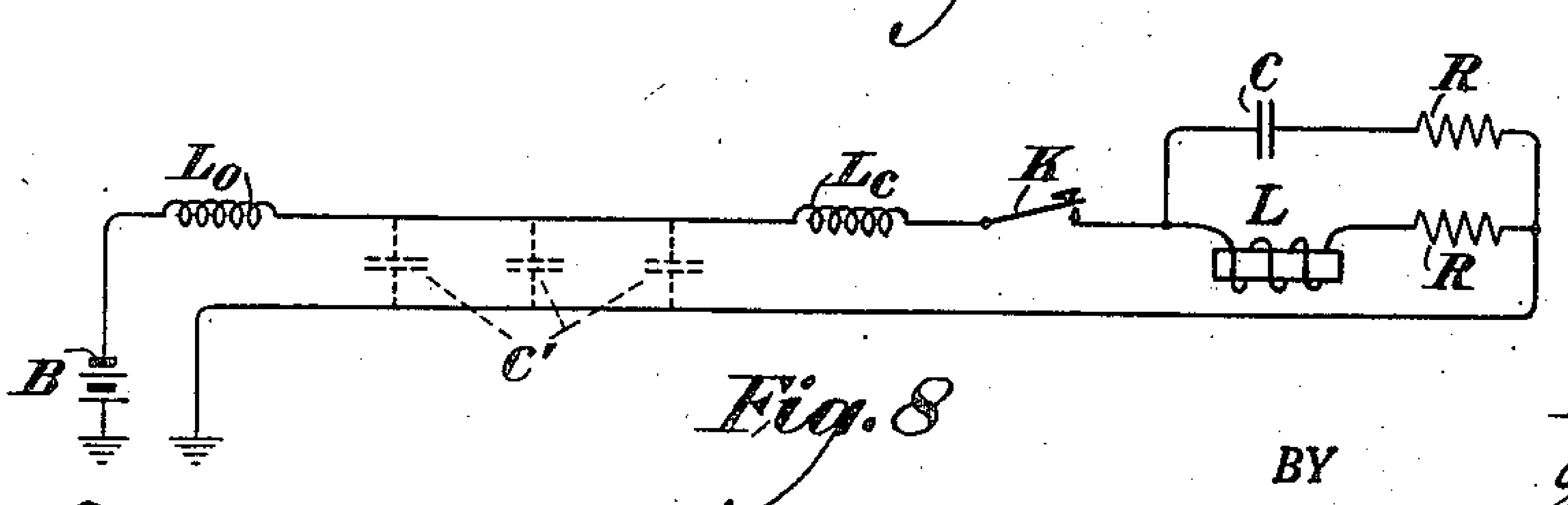

Fig. 8

INVENTOR.
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BY [signature]

ATTORNEY

Patented May 28, 1929. 1,714,567

UNITED STATES PATENT OFFICE.

HARRY NYQUIST, OF MILLBURN, NEW JERSEY, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

TELEGRAPH CIRCUIT.

Application filed December 9, 1927. Serial No. 238,803.

This invention relates to telegraph systems, and more particularly to improvements in a method of and means for insuring symmetrical signals and, hence, lack of distortion in the loop circuits of such systems.

It has been found that it is a common experience with telegraph subscribers' loops that the wave shape is not the same on opening as it is on closing the subscriber's key. This lack of symmetry gives rise to distortion of the signals transmitted by the subscriber and in some instances it has been found necessary to go to considerable lengths to obviate these effects. It is the primary object of this invention to present and illustrate a method for insuring symmetrical signals in telegraph subscribers' loop circuits. The method of the arrangements of the invention comprises so constructing the loop circuit that its impedance as seen from the subscriber's key is a constant resistance at all frequencies. It will be seen from the discussion hereinafter given that this will result in symmetrical signals in the loop circuit. Other objects and features of the invention will appear more fully from the detailed description of the invention hereinafter given.

The invention may be more fully understood from the following description, together with the accompanying drawing, in the Figures 1 to 8, inclusive, of which the invention is illustrated. Figs. 1, 2 and 8 are schematic showings of telegraph loop circuits embodying the principles of the invention. Figs. 3, 4, 5, 6 and 7 are curves showing the wave shape of the signals. Like reference characters have been utilized to denote like parts in all of the figures.

In Fig. 1 is shown symbolically a telegraph loop circuit comprising the battery B, key K, and inductance L to represent the inductance of a series relay, or sounder. To illustrate the method of the invention, which consists in so constructing the loop that its impedance as seen from the subscriber's key is a constant resistance at all frequencies, it has been assumed that all the reactances in the loop are negligible except inductances of series relays or sounders. Furthermore, only one such series relay, as illustrated by the inductance L is shown. The individual relays or sounders will now be equipped with compensating shunts. For example, let a given relay have the inductance L and the resistance r. It may be convenient as a preliminary to add a resistance as shown in series to bring the total resistance up to R. When the shunt which is connected in parallel with the combination of relay and resistance consists of a condenser and resistance in series, the resistance is given the value R and the condenser the value C. The impedance of branch LR as seen from key K is

$$Z_{LR}=R+i\omega L$$

and the impedance of branch CR is

$$Z_{CR}=R-\frac{i}{\omega C}$$

The impedance of the combination as seen from K would be

$$Z=\frac{R^2+i(\omega LR-R/\omega C)+L/C}{2R+i(\omega L-1/\omega C)}$$

If $L/C=R^2$, then

$$Z=\frac{2R^2+iR(\omega L-1/\omega C)}{2R+i(\omega L-1/\omega C)}=R.$$

In other words, by such an arrangement the loop circuit has been constructed so as to comprise a combination presenting the constant impedance R at all frequencies as seen from the key K when the condition $L/C=R^2$ is satisfied.

In order to prove that under the circumstances assumed the waves in the relays are symmetrical in shape, reference is had to Fig. 2. In the loop of Fig. 2, the opening of key K effects the instantaneous insertion of a resistanceless battery B into the circuit whose voltage is so chosen as to bring the current to zero. This is true because since the circuit looks like a resistance at this point, there are no transients in the battery branch, or in other words, that portion of the circuit external to points A and B. Furthermore, the closing of the key K removes this battery. Accordingly, in the loop circuit of Fig. 2, considered external to the points A and B, the opening and closing of the key is equivalent to varying the potential in a constant impedance circuit in equal and opposite steps and will give rise to a symmetrical wave of the shape shown in Fig. 3. It is obvious that in the loop of Fig. 1, considered external to points A and B, the opening and closing of key K is equivalent to the operation already described with respect to Fig. 2 in that it will also give rise to a symmetrical wave of the shape of the curve of Fig. 3. Accordingly, the two loop circuits external to the points A and B are equivalent.

Considering that branch of the loop in Fig. 2 between the points A and B designated by LR, it will be seen that the closing of key K results in applying a positive potential across terminals A and B. This would give rise to a wave in branch LR of the form shown by the curve of Fig. 4. The application of a negative, instead of a positive, potential across terminals A and B would obviously give rise to a wave of the same form but in reverse direction, as shown by the curve of Fig. 5. Let us assume a direct current I flowing through the branch LR due to a positive potential across terminals A and B in Fig. 2. If we now, without removing this positive potential, apply an equal negative potential by closing key K in Fig. 2 at the time indicated by point P, the wave shape will be illustrated by the curve of Fig. 6. This curve is obviously of the same form as that of Fig. 5 except that it starts from I instead of zero. The continued opening and closing of key K would give rise to a signal wave of the form illustrated in Fig. 7, in which the building up of the wave is symmetrical to its decay. In other words, the opening and closing of the key in Fig. 2, which is equivalent to varying the potential in equal and opposite steps in the loop circuit which has been made of constant impedance will give rise to a symmetrical wave.

It has been pointed out heretofore that the two loop circuits of Figs. 1 and 2 considered external to points A and B are equivalent. But the two loop circuits between points A and B are identical with each other. Accordingly, as they are equivalent outside of points A and B and are identical between points A and B, the operation between points A and B must be the same. Accordingly, the operation of key K of Fig. 1 will give rise to a wave of the form shown in Fig. 7, in which the building up of the wave is symmetrical to its decay. In other words, the wave shape of the signals in the relays will be symmetrical and distortion will be obviated.

It is pointed out that the above discussion has dealt with only one relay or sounder such as illustrated by the inductance L. However, if a plurality of relays or sounders existed, each would be provided with a compensating shunt comprising a condenser and a resistance so that the impedance would equal a constant resistance at all frequencies.

It might be desirable to make certain adjustments in that portion of the loop looking in the other direction from the key K, such as to the left, so that the impedance looking in this direction might be equal to a constant resistance at all frequencies. Accordingly, reference may be had to Fig. 8. In this loop circuit, an inductance L_1 is shown. This might represent the sending relay. The equivalent capacity between conductors may be termed C′. The d. c. conductor resistance may be termed R. A compensating inductance L_c is added to build out the loop to satisfy the equation $L/C'=R^2$, where $L=L_o+L_c$. When the equation $L/C'=R^2$ is satisfied, the impedance looking left from the key K will be substantially a pure resistance at the important telegraph frequencies.

While the invention has been disclosed in certain specific arrangements which are deemed desirable, it is understood that it is capable of embodiment in many and other widely varied forms without departing from the spirit of the invention as defined by the appended claims.

What is claimed is:

1. The method of insuring symmetrical signal waves in telegraph circuits, which comprises constructing the circuit so that its impedance as seen from the telegraph key or sending contacts is a constant resistance at all frequencies.

2. A telegraph circuit comprising a key, a resistance and a relay having a certain inductance in series in said circuit, and a shunt circuit around said relay and resistance, said shunt including a condenser and a resistance, the values of said inductance and capacity and resistances being so chosen that the impedance of the combination as seen from said key will equal a constant resistance at all frequencies.

3. A telegraph circuit comprising a key, a resistance R and a relay having an inductance L in series in said circuit, and a shunt circuit around said relay and resistance, said shunt including a condenser C and a resistance R, the values of C, L and R being so chosen that $L/C=R^2$.

4. The method of insuring symmetrical signal waves in telegraph circuits, which comprises constructing the circuit so that its impedance as seen from a telegraph key or sending contacts in either direction is a constant resistance at all frequencies.

In testimony whereof, I have signed my name to this specification this 7th day of December, 1927.

HARRY NYQUIST.