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A. B. CLARK

TELEPHONE REPEATER

Filed July 31, 1919

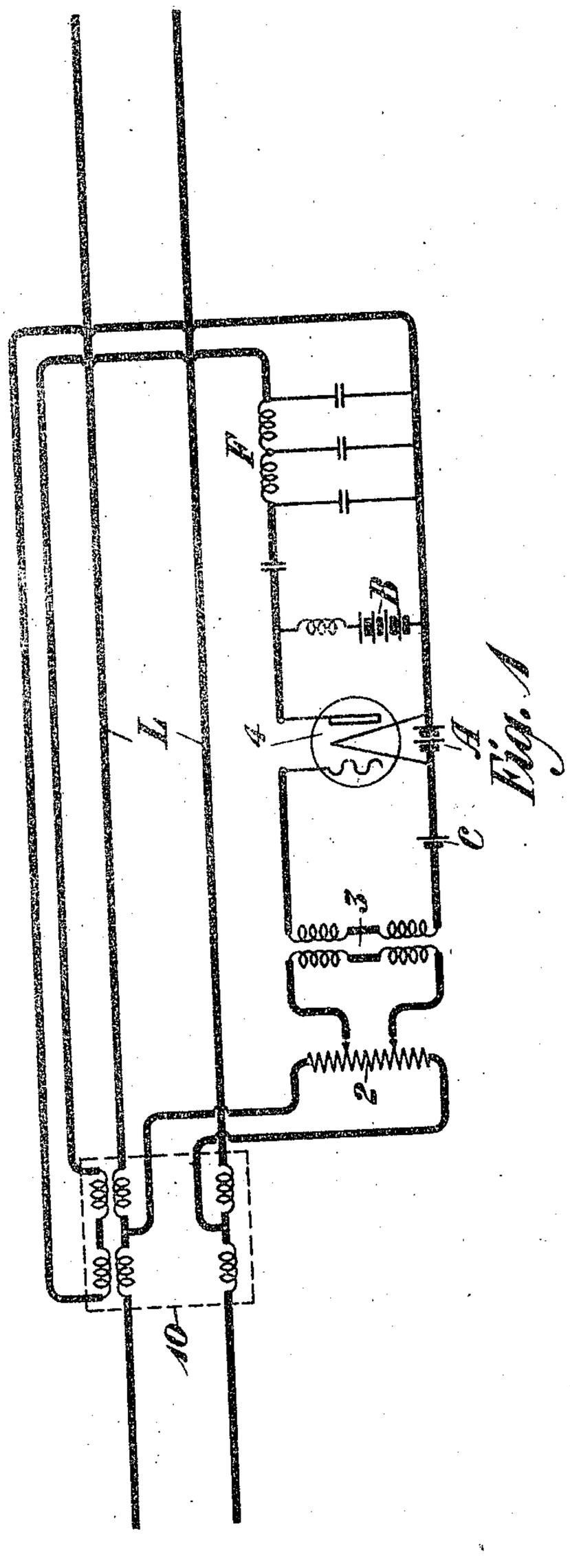


Fig. 1

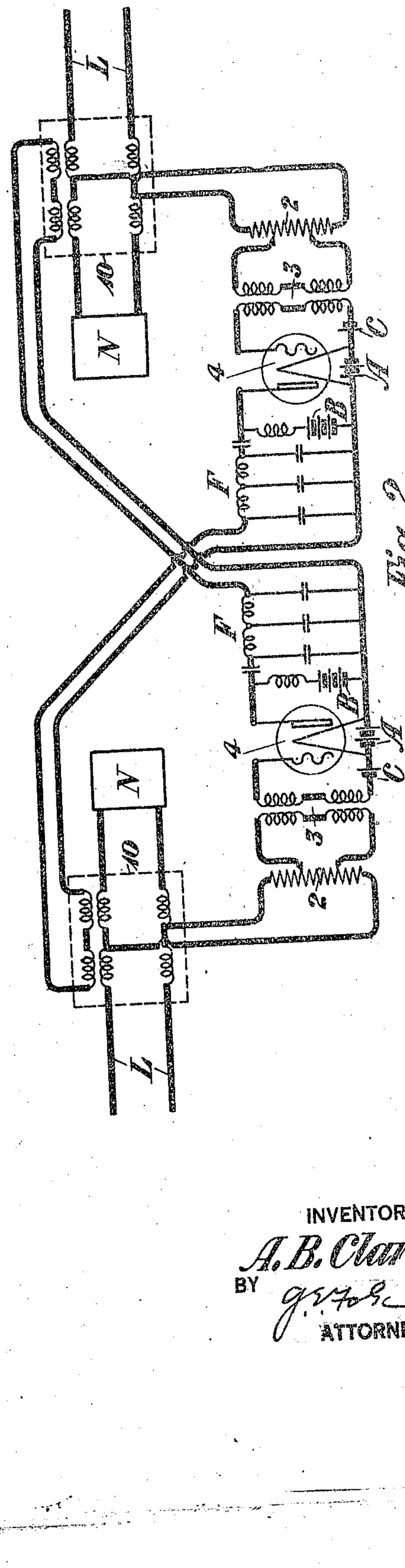


Fig. 2

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# UNITED STATES PATENT OFFICE.

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## TELEPHONE REPEATER.

Application filed July 31, 1919. Serial No. 314,547.

This invention relates to telephone repeaters; more particularly it concerns arrangements of circuits and apparatus for preventing repeater singing.

The singing of a repeater, as well understood, is caused by imperfect conjugacy between the input and output circuits of the repeater, a portion of the output current entering the input circuit and thus causing a local circulation of energy. Perfect conjugacy can be obtained only if the transmission line with which the repeater is associated is in perfect balance at all frequencies of current. Experience has shown that, although it is a comparatively simple matter to balance a line for frequencies within the useful telephone range it is a matter of extreme difficulty and high expense even to approximate line balance for certain frequencies above this range, since the impedance of transmission lines for such frequencies cannot be closely simulated by means of simple networks. A repeater is therefore apt to sing at the high frequencies and it is customary to associate with the repeater a filter which serves to attenuate and approximately extinguish currents above, say 2200 cycles, while it transmits with practically negligible loss frequencies below this range. In the repeaters now in use this filter is associated with the input circuit where it suppresses the high frequencies before they reach the amplifying device. This arrangement is open to certain objections explained hereinafter and the essence of the present invention is to provide a new and improved arrangement of the repeater apparatus in which arrangement a filter is associated with the amplifying device in its output circuit.

The above and other features of this invention will be readiy understood from the following description considered in connection with the accompanying drawing, in which Figure 1 is a diagrammatic view showing an arrangement of apparatus and circuits embodying this invention associated with a well known type of one-element repeater, Fig. 2 being a diagrammatic view similar to Fig. 1, showing the arrangement of this invention associated with a well known type of two-element repeater.

In Fig. 1, reference character L designates a telephone line across which is bridged a potentiometer 2 having associated therewith in variable relationship the input transformer 3 of an amplifying device which is here shown as an electron tube 4. This tube is provided with the usual filament, plate and grid, supplied with current and potential by the batteries A, B and C, respectively. The output circuit of the tube is led through a filter F to the output transformer 10, the secondary windings of which transformer are inserted in series with the line conductors and arranged symmetrically with respect to the points at which the potentiometer 2 is connected to the line. The sections of the line L extending to the left and to the right of the repeater are balanced for currents of voice frequencies in order to prevent singing of the repeaters at these frequencies. Balance should also exist between the two conductors of each section of the line in order to prevent noise due to extraneous disurbances. The parts of the repeater conductively associated with the line are therefore balanced, each of the variable taps of the potentiometer being placed at an equal distance from the adjacent terminal.

The manner in which the repeater operates is briefly as follows: Part of the current in line L is shunted by the potentiometer 2 and enters transformer 3, by means of which it is impressed on the electron tube. This device amplifies the current and causes it to flow through filter F into transformer 10, whereby it is returned to the line L. The filter suppresses currents of a frequency higher than 2200 cycles, and for frequencies below this range substantially no potential difference between the terminals of the potentiometer is produced by the electro-motive force impressed on the line conductors by transformer 10, because of the balance of the line. Singing of the repeater at the higher frequencies is thus prevented by the filter, whereas at the lower frequencies it is effectively precluded, when the tube is operating with normal amplification, by the line balance. Where desired, the filter may be arranged to attenuate also currents of low frequency, permitting only such currents to pass as are necessary for the transmission of intelligible speech.

The range of frequencies at which a filter is effective is determined by the impedances of its elements, and reference may be had to the patent of G. A. Campbell, 1,227,114, May

22, 1917, for "electrical receiving, translating or repeating circuit", for a description of the manner in which the said impedance values may be determined. In the said patent and in fact in present practice, the filter is in conductive connection with the line wires. To preserve the balance of the line, each series impedance of the filter conductively connected in one wire must be balanced by a like impedance connected in the other. Each series inductance coil of the filter is therefore in practice provided with two windings, one in each line conductor, and for perfect balance these windings must be alike in every respect.

The filter of the present arrangement is associated with the output circuit of the electron tube. This circuit has no conductive connection with the line and need therefore not be balanced. The inductance coils or other impedance of the filter serially connected into one conductor of the circuit need therefore not be balanced by like coils or other impedances in the other conductor of the circuit. Moreover, since for any cut-off frequency the impedances of the elements of a filter are determined by the impedance of the circuit into which the filter is connected, it is readily understood that when a filter is conductively associated with a transmission line its impedances must be calculated relative to the impedance of the line, a filter of different impedance relations being necessary for each different line. In the present arrangement, however, the impedance of the filter is determined by the impedance of the output circuit of the amplifying device, which impedance is readily determinable and does not vary with each line. The adjustment of the filter impedance to the line is readily made at the transformer 10. Because of the high impedance of the output circuit of the electron tube the condensers required for the filter are quite small and inexpensive compared to the condensers required in the arrangement heretofore used.

Moreover, under the conditions usually existing in an electron tube telephone repeater circuit the grid is substantially an insulated charged body except for its connection to the external circuit. The impedance of the input or grid circuit of the electron tube is therefore extremely high, being principally the reactance due to the electrostatic capacity of the grid to its surroundings. Furthermore, to obtain an adequate output of energy from the electron tube a voltage must be impressed upon its grid which is high in comparison with those usually existing in telephone circuits, consequently the input transformer 3 must have a large transformation ratio. This high transformation ratio results in practical difficulties of transformer design. A transformer of reasonable size and cost having a sufficiently high self-inductance for satisfactory performance at low frequency, has so much capacity in its windings as to be unsatisfactory at high frequencies. The best available compromise design has a lower self-inductance in proportion to the impedance with which it works than is the case with other transformers in the repeater circuit, and in addition the effects of capacity are great enough to be injurious. The internal capacity of the input transformer together with the capacity of the grid and connecting wires causes impedance effects at high frequencies and the relatively low self inductance causes impedance effects at low frequencies that are all unfavorable to the correct functioning of the filter when the same is connected, as heretofore, into the input circuit of the tube. Associating the filter with the output circuit removes it from the influence of the input transformer thus improving its behavior and in turn improving the characteristics of the whole repeater set. In addition, due to its relatively low inductance, the efficiency of the input transformer is reduced at low frequencies by any impedance in series between it and the line. Associating the filter with the output circuit of the electron tube thus improves the behavior of the input transformer by removing some of the series impedance.

This invention therefore provides for an arrangement of the repeater circuits which results in a cheaper and simpler filter which has no tendency to unbalance the line. It also improves the behavior of both the input transformer and the filter by separating them from each other.

The circuit arrangement of Fig. 2 shows this invention associated with a repeater of the familiar two-element type. The line L in this arrangement is cut at the place where the repeater is installed, both portions of the line being balanced by networks N. An amplifying device, herein shown as an electron tube 4, is provided for each portion of the line and associated therewith by a potentiometer 2 and a transformer 3, the output circuit of each tube being associated with the portion of the line opposite thereto by means of an output transformer 10. A filter F is inserted into the output circuit of each tube, similarly as in Fig. 1, and prevents high frequency disturbances originating in one portion of the line from being transmitted to the other portion thereof, thus prohibiting these currents from causing singing of the repeaters, when unbalance exists between the lines and the networks, similarly as described hereinbefore. The arrangement of Fig. 2 has the same advantages relative to simplicity and cheapness of the filter as the arrangement of Fig. 1.

Although only two forms and arrange-

ments of apparatus and circuits embodying this invention are shown and described herein, it is to be understood that various changes and modifications may be made therein within the scope of the appended claims without departing from the spirit and scope of the invention.

In both Fig. 1 and Fig. 2 it will be noticed that the potentiometer 2 is provided with two adjustable contacts and that these are shown substantially at equal distances from the ends of the winding. Thus it will be seen that the potentiometer 2 stands in balanced relation to the two sides of the line L. Adjustment of the potentiometer may be made by moving the two taps in equal amounts oppositely so as to preserve the balanced relation with respect to the line L.

What is claimed is:—

1. In combination, a transmission line having its two sides in balanced relation, a vacuum tube amplifying device, a circuit inductively associating one side of said device with said line, and a wave filter in said circuit, said wave filter comprising an impedance device in unbalanced relation to the two sides of the said circuit in which it is comprised.

2. In combination, a transmission line having its two sides in balanced relation, a vacuum tube repeater, a circuit inductively associating one side of said repeater with said line, said circuit having its two sides in balanced relation, another circuit associating the other side of said repeater with said line and having its two sides in unbalanced relation, and a wave filter in said last mentioned circuit.

3. In combination, a transmission line of such length as to be subject to considerable attenuation and external interference, a repeater therefor comprising an electron tube amplifying device having an output circuit of high impedance relative to the impedance of the line, inductive means for associating said circuit with said line and a filter in said output circuit, said filter being located between said amplifying device and said inductive means.

4. In combination, a transmission line having its two sides in balanced relation, a vacuum tube repeater, a circuit connected therewith and having inductive relation with said line, and a wave filter of recurrent periodic structure comprised in said circuit and having certain elements in unbalanced relation to the sides of said circuit.

5. In combination, a repeater, a transmission line and a balanced potentiometer connecting said line and said repeater.

6. In combination, a transmission line having its two sides in balanced relation and a repeater comprising an amplifying element, said repeater also comprising apparatus connected with the line by a pair of conductors, said apparatus being in unbalanced relation to said pair of conductors and said apparatus being placed on the output side of the amplifying element of the repeater.

7. In combination, a transmission line, a repeater comprising apparatus in unbalanced relation to the two sides of the line, said apparatus being placed on the output side of the repeater, and a balanced potentiometer connecting the repeater with the line on the input side.

8. In combination, a transmission line having its two sides in balanced relation and a repeater comprising a one-way amplifying element, said element having its input side connected with the line by means of a balanced potentiometer.

9. In combination, a repeater and a transmission line, said repeater comprising a three-electrode vacuum tube and a balanced potentiometer, the said vacuum tube having its input side connected through said potentiometer with said line.

In testimony whereof, I have signed my name to this specification this 29th day of July 1919.

ALVA B. CLARK.