

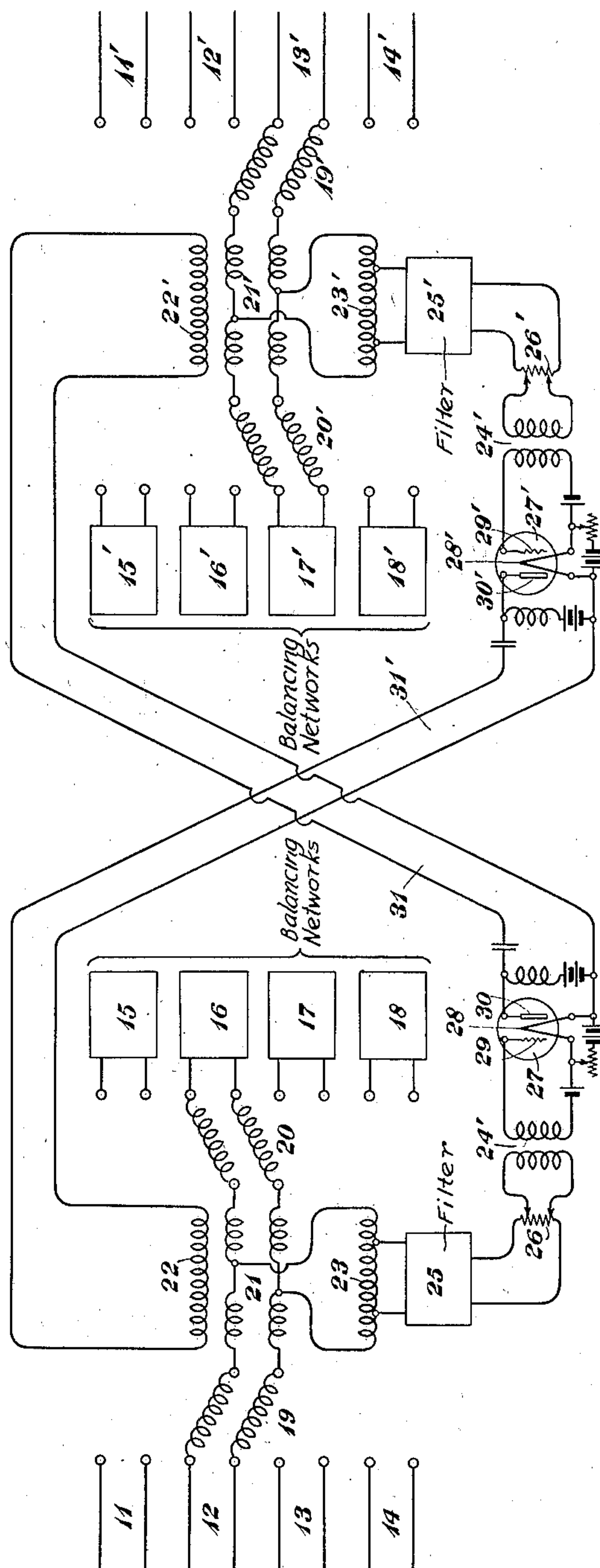
Jan. 25, 1927.

1,615,259

A. B. CLARK

TELEPHONE REPEATER SYSTEM

Filed March 18, 1921



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TELEPHONE REPEATER SYSTEM.

Application filed March 18, 1921. Serial No. 453,304.

The principal object of my invention is to provide a new and improved repeater installation adapted for connection with telephone lines of various characteristic impedances. This and other objects of my invention will be appreciated after the disclosure of a specific embodiment thereof and a discussion of the principles involved in its operation. I now proceed with such disclosure, leaving the invention to be defined in the appended claims.

The accompanying drawing is a diagram showing my invention embodied in a repeater adapted to connect any two of a plurality of lines radiating therefrom.

A plurality of different lines 11, 12, 13, 14, 11', 12', 13' and 14' come to terminals at one repeater station. These lines may be widely different in their characteristic impedances. One of them may be an open wire line, another may be a cable pair, one may be an unloaded line, another may be loaded continuously, another may have lumped loading. It is desirable to terminate each of these lines when it is in use by an impedance approximating its own characteristic impedance in order that waves reaching the repeater may not suffer partial reflection which would cause transmission losses and distortion at this repeater and would affect detrimentally the impedance balance of repeaters at other stations on the line. Instead of specially designing the repeater to adapt it for the characteristic impedance of a particular line with which it is to be used, I have devised a system by which a given repeater can be immediately connected in between any two of the lines without occasioning serious reflection effects.

For each of the lines 11, 12, etc., a respective balancing network is provided, such as 15, 16, etc. Each of these networks is an artificial line having approximately the same impedance characteristic as its corresponding geographical line.

A "hybrid-coil" transformer 21—22 is provided. Its coils 21 have two pairs of terminals for connection between any one of the lines and its corresponding artificial line. The facility for making these various connections is indicated by the flexible conductors 19 and 20.

Bridged across the transformer coils 21 is

the primary coil 23 of an auto-transformer, a minor portion of whose windings are included in the circuit leading through the wave filter 25 to the potentiometer 26, from which the input circuit goes to the transformer 24 and thence to grid 29 and filament 28 of the audion 27. From the filament 28 and plate 30 of this audion 27 the output circuit goes through the conductors 31 to the coil 22', which matches the coil 22 of the hybrid-coil transformer already described. The repeater has bilateral symmetry which is indicated by the use of the primed reference characters, and the duplicate parts need not be described verbally.

There is one magnetic circuit for the coils 21 and 22. Linked with this magnetic circuit the coil 22 has a large number of turns and the coils 21 only a comparatively small number.

The energy of incoming currents from the left over the line 12 will mostly go through the transformer windings 21 and on into the artificial line 16. It is true that there is a bridge across the coils 21 comprising the coil 23, but this is a path of high impedance, so that comparatively little current will be diverted through the bridge. It is also true that the coil 22 stands in inductive relation with the series coils 21, so that some current will be induced in the circuit of the coil 22, but since the windings of the coils 21 are comparatively few, the electromotive force drop through these coils is small and there will be little energy absorption from them into the circuit of the coil 22; in other words the series impedance that they introduce between the line and artificial line is relatively small.

Since the artificial line 16 matches the line 12, and since there is little opportunity for energy to be diverted at the transformer 21—22 or its bridge 23 as just pointed out, it follows that the wave from the line 12 will go through into the artificial line 16 with very little loss, and the impedance that the incoming wave encounters on entering the repeater is substantially that of the artificial line which in turn has the correct value for terminating the line. In this respect my invention differs from an arrangement that is common, where practically none of the incoming energy reaches the artificial line and the impedance encountered by the incoming wave on entering the repeater depends upon

the structure of the repeater circuit and not on the artificial line.

While it might appear as a disadvantage that the major portion of the energy of the incoming current along the line 12 goes to the artificial line 16 instead of to the input element of the repeater, this disadvantage, such as it is, is easily overcome by using a sufficient degree of amplification. In other words, while the currents put through the filter 25 have only a fraction of the energy of those that come in over the line 12, they have the same wave form and are readily amplified to the necessary degree by the audion 27. The connection between the coils 21 and 22 that prevents excessive energy diversion at this point, as heretofore described, results in a somewhat ineffective transfer the other way; that is, when repeating from the right to the left in the drawing; that is, from the coil 22 as primary to the windings 21 as secondary. Here again the unfavorable relation for energy transfer is readily compensated by the amplification by the repeater element.

It will be seen that I have provided a system in which the passive impedance of the repeater approximates closely to any type of line on which the repeater may be required to work. In other words, I have succeeded in securing the result that the passive impedance of the repeater circuit will be correct for any line that may be connected therewith, whether it be loaded or not, and whether it be of the open wire kind or a pair of conductors in a cable. The respective network for the line considered is the electrical counterpart of the line and terminates the line perfectly, that is, it introduces no irregularity in transmission. This assumes that in the case of lines having a lumped loading, the termination of the line is with a half coil or a half section between the coils. By connecting the repeater apparatus between each line and its balancing network so that it will have a negligible effect, I secure and preserve the result that the repeater system will have a perfect passive impedance.

To illustrate the resultant gain with my system, let us consider a special case. It is well understood that a repeater of the type illustrated in the drawing may ordinarily give a net gain of about 21 standard miles, a standard mile corresponding to the formula

$$d = 21.13 \log_{10} \frac{I}{i}$$

where d gives the number of standard miles, i the input current, and I the output current. Of course the total amplification produced by the repeater tube is greater than 21 miles. In the known repeater systems of this type prior to my invention, something like $6\frac{1}{2}$

miles might be lost in the hybrid coils with further loss in the wave filters, etc. Assume for the purpose of the illustration that the net total gain available with a single audion element is about $27\frac{1}{2}$ miles. This corresponds to a current amplification of about 20 times and an energy amplification of about 400 times.

The foregoing is based on the assumption that the repeater input is connected to the bridge terminals of the hybrid coil, but instead of this, I connect it through an auto-transformer 23, thus causing the amount of energy taken from the line to be as small as I please. This makes the effect of the bridge upon the passive impedance of the repeater to be correspondingly small. Similarly I make the effect of the output coil 22 upon the passive impedance of the repeater to be as small as I please. For the purpose of this illustrative example, let us assume that the bridge and the output coil are so designed as to affect the line impedance by only 10 per cent. The passive impedance of the repeater, then, will not depart more than about 20 per cent from the ideal, indeed the departure will be much less because the series and shunt impedances of the repeater circuit tend to produce opposite effects. In order that the effect of the bridge circuit shall be limited to 10 per cent of the impedance of the network its impedance must be 9 times the impedance of the network and about $\frac{1}{10}$ of the energy entering the repeater will reach the bridge circuit. Similarly if the winding 21 is such that its effect upon the impedance is limited to 10 per cent of the network impedance only about $\frac{1}{10}$ of the possible power output of the tube can be utilized in the line. Accordingly each repeater element will now be required to produce an energy amplification of approximately $10 \times 10 = 100$ times, to overcome the losses due to the inefficient transformer couplings. However, since each audion is capable of amplifying the energy 400 times, we get a net amplification of $400/100 = 4$ times, which corresponds to a gain of about $6\frac{1}{2}$ standard miles. Thus it will be seen that in spite of the special transformer design with its inefficient coupling, I secure a gain of $6\frac{1}{2}$ miles and accomplish this result without substantially affecting the passive impedance which the repeater offers to the line.

By using more than one audion element in tandem instead of the single one shown in the diagram I could evidently increase the net resultant gain obtainable with the repeater.

I desire it to be understood that the repeater may serve to connect any one line with any other line. In Fig. 1 I have shown the connection between lines 12 and 13', but the connection might be made from

line 12 to line 13 by attaching the conductors 19' and 20' respectively to the line 13 and the artificial line 17.

I claim:

6 1. In combination, a telephone line and a repeater, said combination comprising an artificial line connected with the telephone line, the series impedances offered by the repeater to the line being made small and
10 the shunt impedances made large so that the input impedance is determined by the impedance of the artificial line.

15 2. In combination, a plurality of telephone lines, respective artificial lines therefor, a repeater, and means to connect any two said telephone lines through said repeater, the series impedances offered to the incoming waves being made small and the shunt impedances large so that the input impedance
20 to each telephone line is determined by the impedance of its artificial line.

25 3. In combination, a telephone line and a balancing artificial network, a three-winding transformer between them with input and output connections, the series impedance of these connections being small from the line and the shunt impedance being

large from the line whereby most of the current from the line goes through to the artificial network and only a small part goes
30 into the said connections.

4. The method of repeating between any two of more than two lines of various characteristic impedances with respective balancing networks which consists in passing
35 incoming energy from one such line through to its balancing network with diversion of only a small portion of energy for amplification, and applying the amplified energy to the outgoing line through a relatively in-
40 efficient connection.

5. The method of repeating with amplification on a telephone line without matching the impedances of the repeater circuits to the line which consists in sending the major
45 part of the incoming energy on the line through and diverting only a small part thereof, amplifying this small part and applying the amplified energy relatively in-
50 efficiently to the line.

In testimony whereof, I have signed my name to this specification this 15th day of March, 1921.

ALVA B. CLARK.