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A. B. CLARK ET AL

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TELEPHONE REPEATER CIRCUITS

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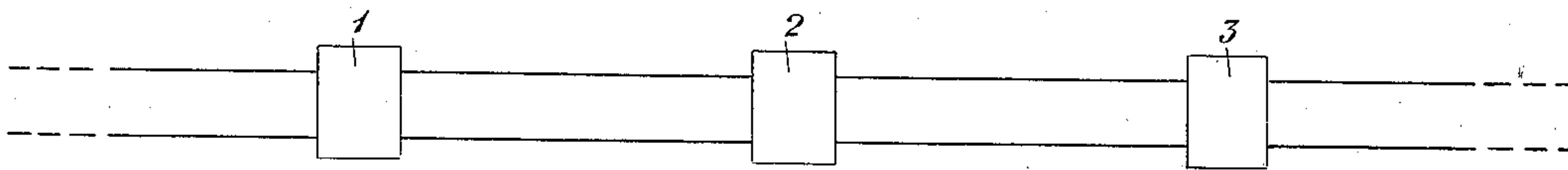


Fig. 1

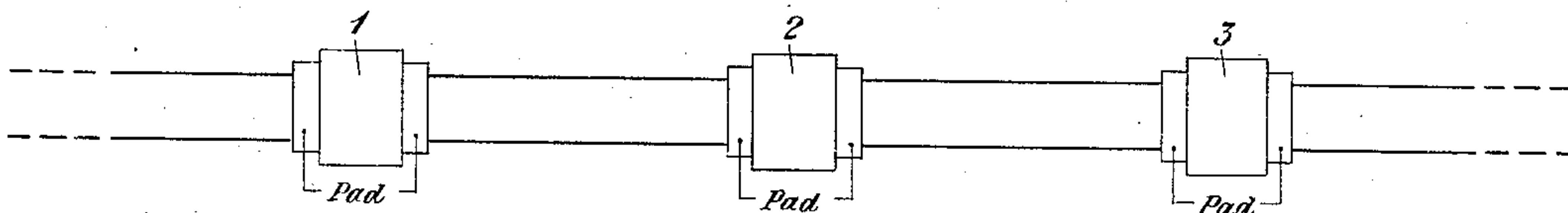


Fig. 2

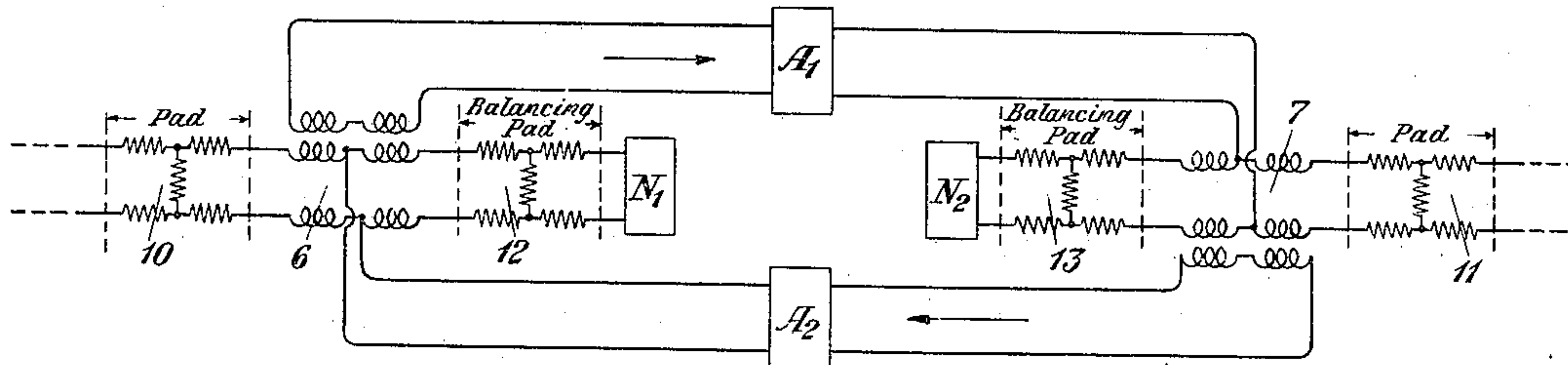


Fig. 3

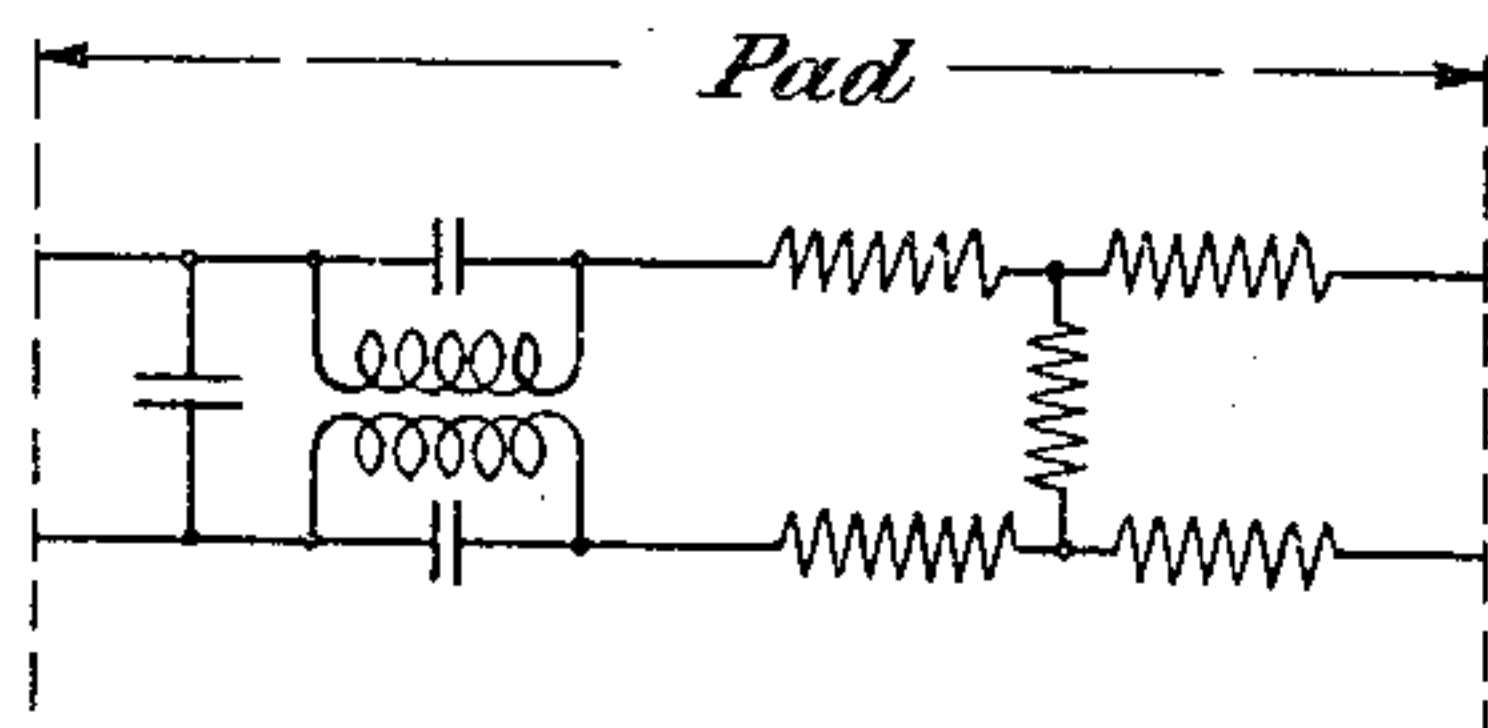


Fig. 4

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TELEPHONE REPEATER CIRCUITS

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This invention relates to telephone repeater circuits and more particularly to means for reducing the echo currents in such circuits.

When a telephone current traverses a transmission line, there will be, as in the case of any wave motion, some reflection occurring at all points in the line where the transmission characteristics change. Some of these changes arise from accidental irregularities of many sorts; the extent to which these are eliminated depending upon the care with which the line, itself, is constructed. Other changes arise in connection with apparatus associated at the terminal or at intermediate points of the line and here, as in all other cases, the amount of reflection depends on the degree to which the transmission characteristics of the apparatus differs from that of the line. In modern long line transmission, where repeaters are employed, the problem of these reflections, yielding pronounced echoes, has become an increasingly more exacting one. In such a line, the reflections may occur at the repeaters or at other points in the line. If these latter are large or numerous and the repeaters are far apart, then the reflections at the repeaters may be relatively unimportant, but as the line irregularities are reduced by better construction or as the repeaters are put closer together, the reflections at the repeaters may become the important consideration. It is the purpose of this invention to reduce the reflections at the repeaters to as low a value as possible, and we accomplish this by associating with the repeater suitable networks which we will call pads and which, in general, introduce attenuation in the manner hereinafter described.

In the case of a wave traveling along a given channel, it is theoretically possible to make the reflection at any point to which a piece of apparatus is connected equal to zero by making the impedance, as measured when looking into the apparatus, the same as that if the channel were continued indefinitely with no irregularities. In general, this is not the condition obtaining at a repeater station on a telephone line and we propose to make it as nearly so as possible by the addition of the

proper net work or pad mentioned above. The invention will be better understood from the following description and the accompanying drawing in which Figure 1 represents a section of a transmission line with a plurality of repeaters thereon. Fig. 2 represents a similar line with repeaters, these repeaters being supplied with certain forms of networks to carry out the purpose of this invention. Fig. 3 shows a specific form which the repeater circuit and associated network or pad may take on and Fig. 4 shows a modified form of the network to be used.

Referring more particularly to Fig. 1, the reference characters 1, 2 and 3 represent repeaters on a transmission line, these repeaters being of any suitable form, such as that well known as the "22 type repeater". An electric wave traveling in either direction on this line will suffer a certain amount of reflection at each irregularity encountered, some of these comprising the repeaters themselves and others being irregularities on the line between the repeaters. In general, it is the practice to make the gain at each of these repeaters as large as the line will permit, this limit being determined in the main by the amount of the reflections for even though the gain be not so great as to cause "singing", the reflection or echo effects may become troublesome.

In accordance with this invention, we propose to diminish the reflections which occur at a given repeater by introducing at the repeater one or more networks possessing attenuation, the network being designed so that the impedance as measured from the line and looking through the network into the repeater will be equal to that of the line itself if extended indefinitely, or as nearly so as called for by practical considerations.

For precise balance, the type of network used will, obviously, depend upon the the impedance characteristics of the repeater and of the line, but even though an exact simulation of the line impedance may not be feasible, an approximation thereto may be quite readily obtained. One form of network is shown in connection with Fig. 3 in which there is shown a 22 type repeater circuit, this circuit com-

prising two hybrid coils 6 and 7 to which are associated in conjugate relationship the amplifiers A_1 and A_2 , adapted to permit speech in the one direction or the other. In order to obtain the conjugate relation with the hybrid coils, there are shown the balancing networks N_1 and N_2 , these being connected in a manner now well understood in the art. In front of the hybrid coil 6, we introduce a network or pad 10 which is here shown as made up of resistances in series and in shunt to the line. A similar pad 11 is shown on the further side of the repeater. In order that the repeater circuit, as a whole, shall remain balanced, it will be necessary, of course, to associate with the balancing networks N_1 and N_2 , balancing pads 12 and 13 which are identical to the pads 10 and 11 and in view of the simplicity of the form of these networks, it is evident that such identity can very readily be maintained. While these networks 12 and 13 have been shown as separate from, but associated with, the networks N_1 and N_2 , it is to be understood that in practice it may be desirable to incorporate them as part of the networks N_1 and N_2 , either by the inclusion of these elements with those comprising the network N_1 or by changing the value of the elements of these networks N_1 and N_2 to give the resulting network the desired characteristic.

In some cases, in order to obtain closer simulation between the line and the repeater with its pads, it may be desirable to include a certain amount of reactance, properly distributed, into the pad. This is shown, for example, in Fig. 4, where, in addition to the resistances of the element 10, there is shown one arrangement of condensers and inductances to give certain impedance characteristics. Other arrangements of condensers and inductances would be adapted for other impedance characteristics.

In order still better to understand the operation of this invention, we may consider a wave coming up to a repeater on a line in which all repeaters are set for as high a gain as is feasible without the echo or unbalance conditions becoming troublesome. Let us assume that a repeater such as 2 of Fig. 2 is provided with pads and that the direction of transmission is from left to right. In view of the pad, the reflected wave or echo will be substantially reduced. The portion transmitted will suffer a certain amount of attenuation in the front pad which may be represented by m transmission units. There may also be an equal amount of attenuation through the pad on the further side of the repeater, giving a total loss of $2m$ transmission units. The direct loss thus introduced can, of course, be readily made up by increasing the gain of the repeater, the ability to introduce as much gain as desired being limited only by the effects of echo, as before explained.

Assuming now that the overall gain of re-

peater 2, plus its pads, has been adjusted so as to be just equal to what it was before without the pads, let us now examine the echo conditions with a view to seeing whether they have been improved. Evidently, those echoes which are due to reflections at the points where junction is made between repeater 2 and the lines on either side, have now been attenuated by twice the loss in each pad; i. e., an additional loss of $2m$ has been introduced into each one of these echo paths. The effect of these particular echoes is, therefore, made less serious. The total gain introduced into the circuit, being limited by the composite effect of all of the various echoes, can, therefore, be increased, because of the fact that certain of the echoes have been reduced in magnitude. It makes little difference in practice at what point in the circuit this additional gain is introduced.

In a similar way, associating pads with the other repeaters in the circuit will have the effect of reducing the magnitude of other echoes. Consequently, each time the pads are added to a repeater, a further increase in the net gain, i. e., a further reduction in the overall loss of the circuit, is made possible.

While this invention has been described with special reference to voice frequency telephone lines, the principle involved is equally applicable to other signaling systems such as those using carrier currents for telephony or telegraphy and it would be particularly useful where special conditions make it necessary to place repeaters abnormally close to each other in otherwise regular high grade line.

What is claimed is:

1. In a transmission line comprising repeaters, the method of reducing echo effects which consists in permanently introducing attenuation at a repeater and permanently stepping up the gain at that and the adjacent repeaters.

2. In a transmission line comprising repeaters, the method of reducing echo effects which consists in permanently introducing attenuation at the repeaters and permanently stepping up the gain of the repeaters.

3. In a transmission line comprising repeaters, the method of reducing echo effects which consists in introducing attenuation at each side of the repeaters and stepping up the gain of the repeaters.

In testimony whereof, we have signed our names to this specification this 3rd day of August, 1926.

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