MULTIWAY CONNECTION FOR SIGNALING CIRCUITS

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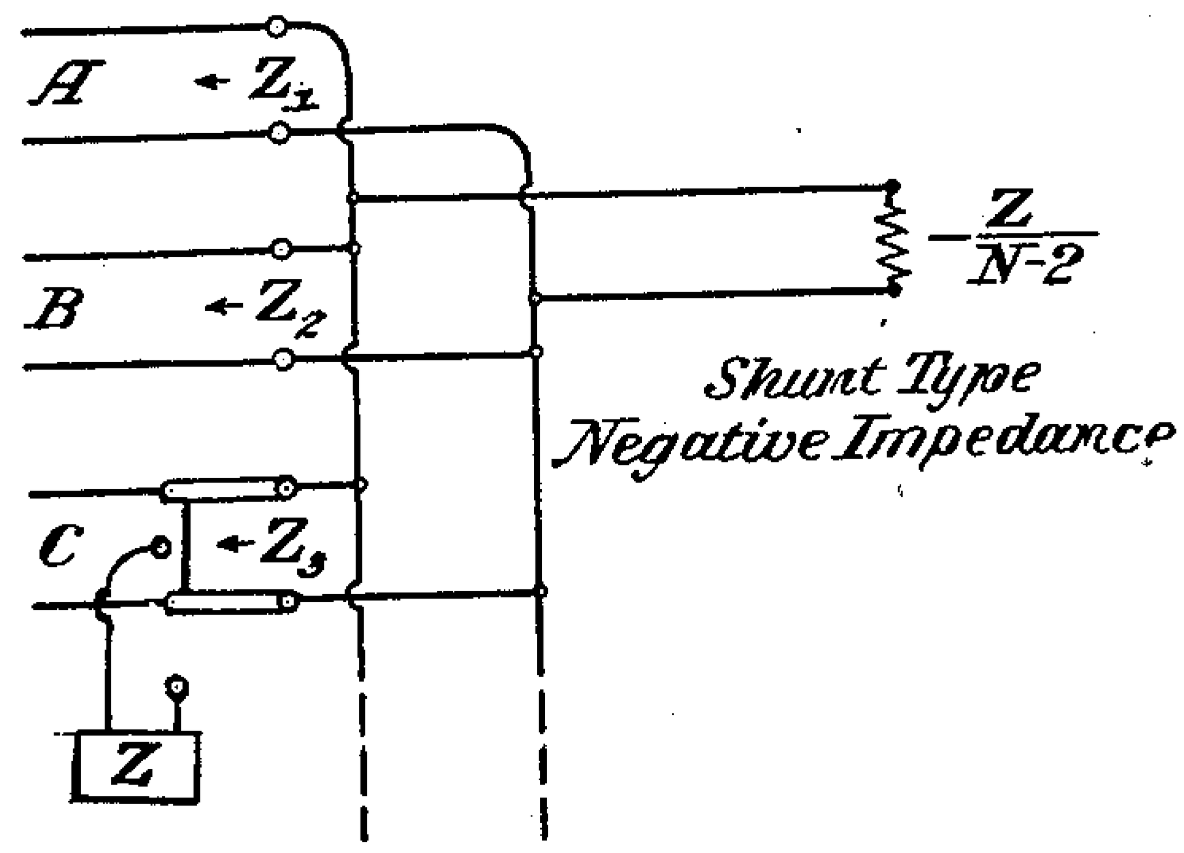


Fig. 1

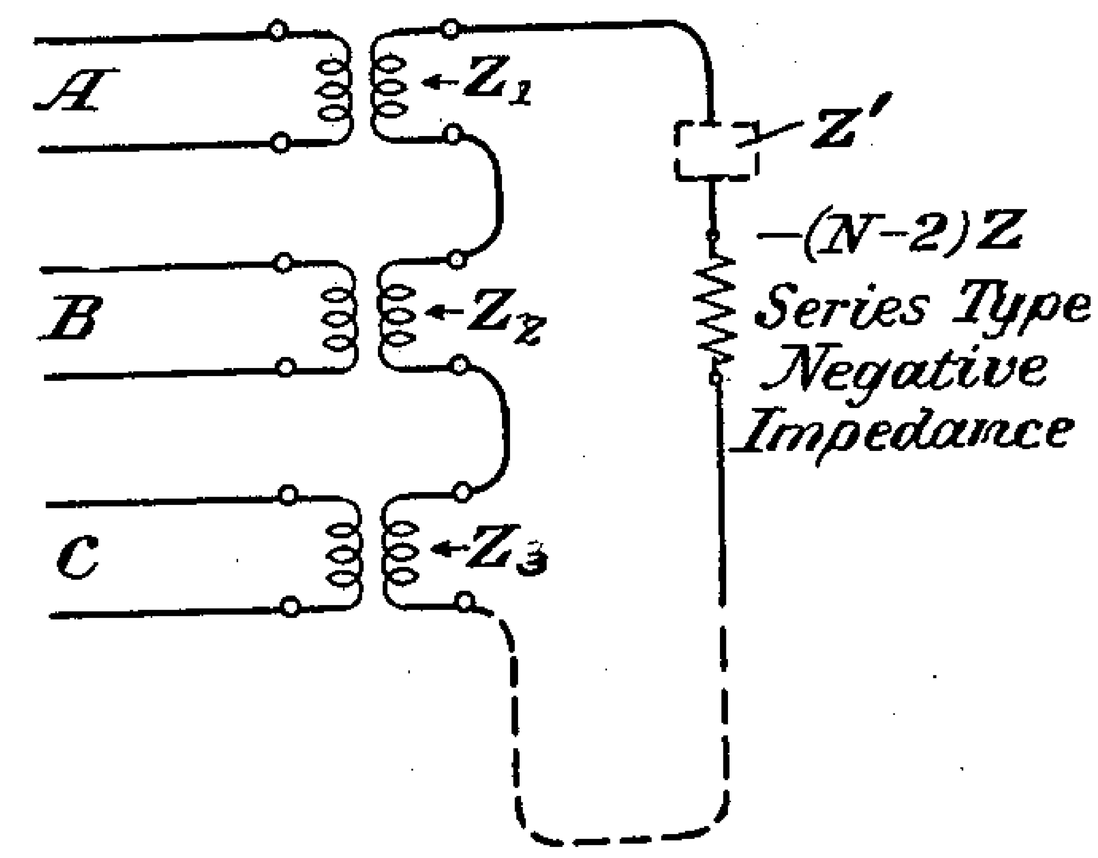
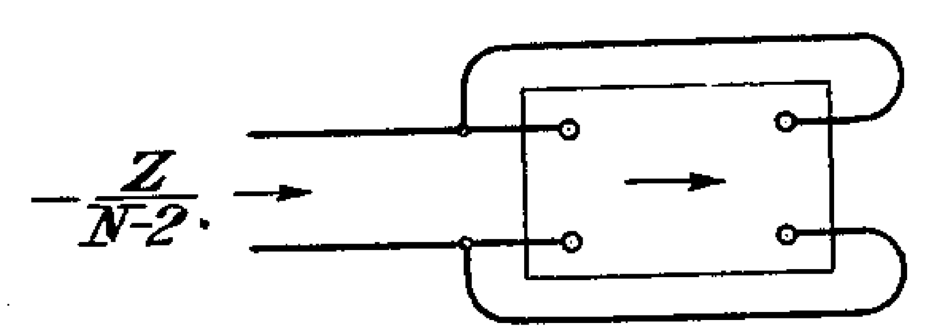
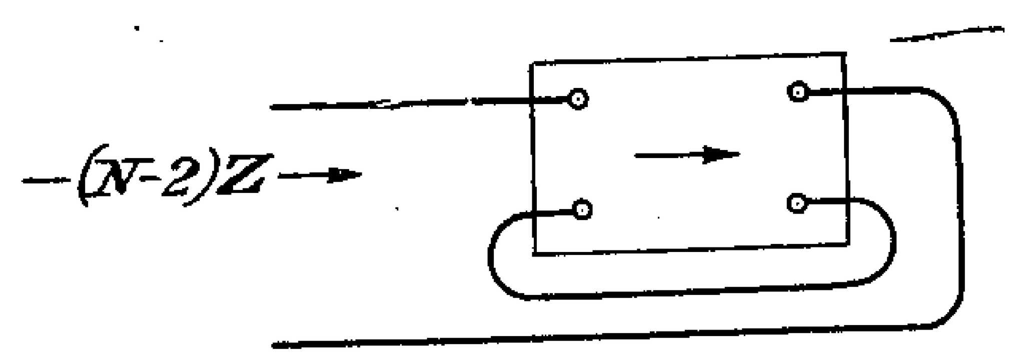


Fig. 2



Shunt Type Negative Impedance

Fig. 3



Series Type Negative Impedance

Fig. 4

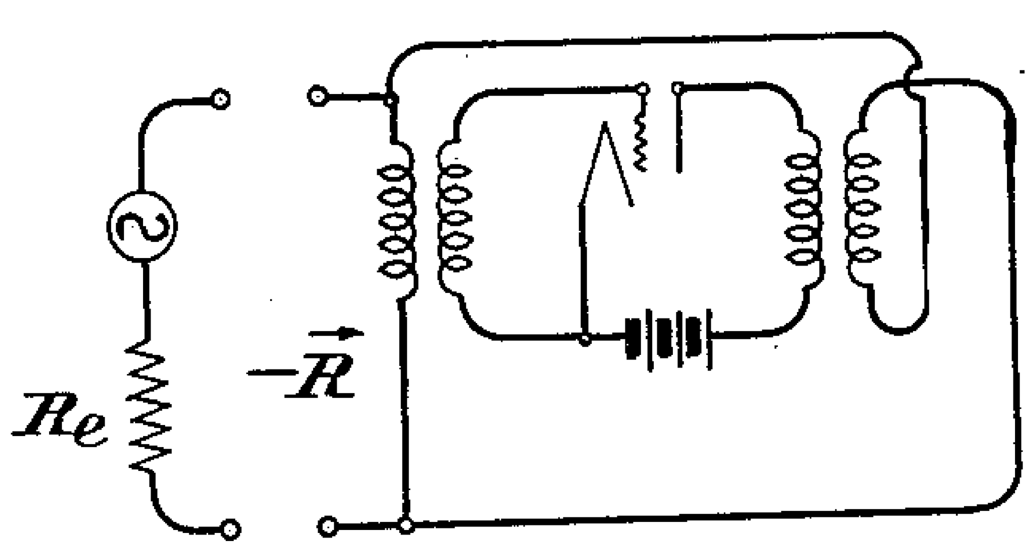


Fig. 5

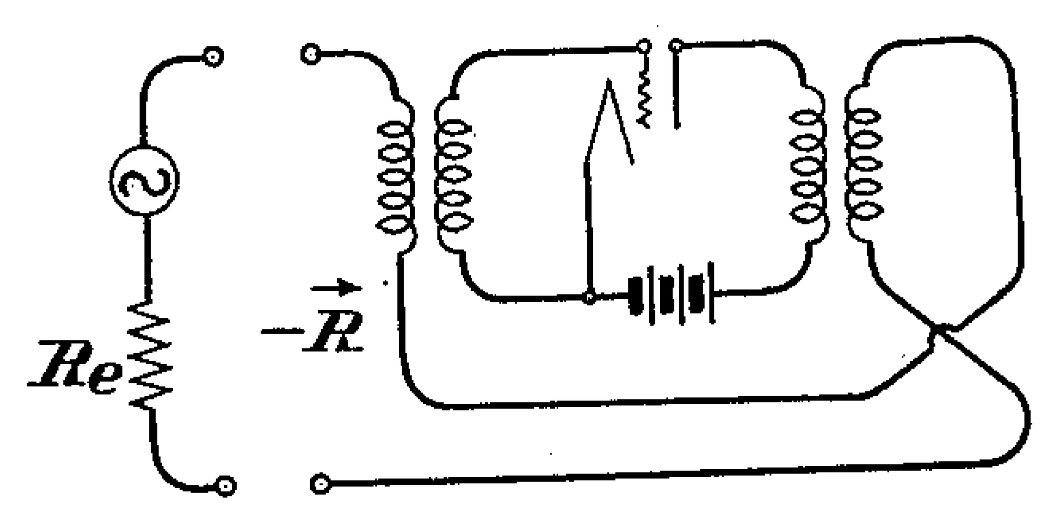


Fig. 6

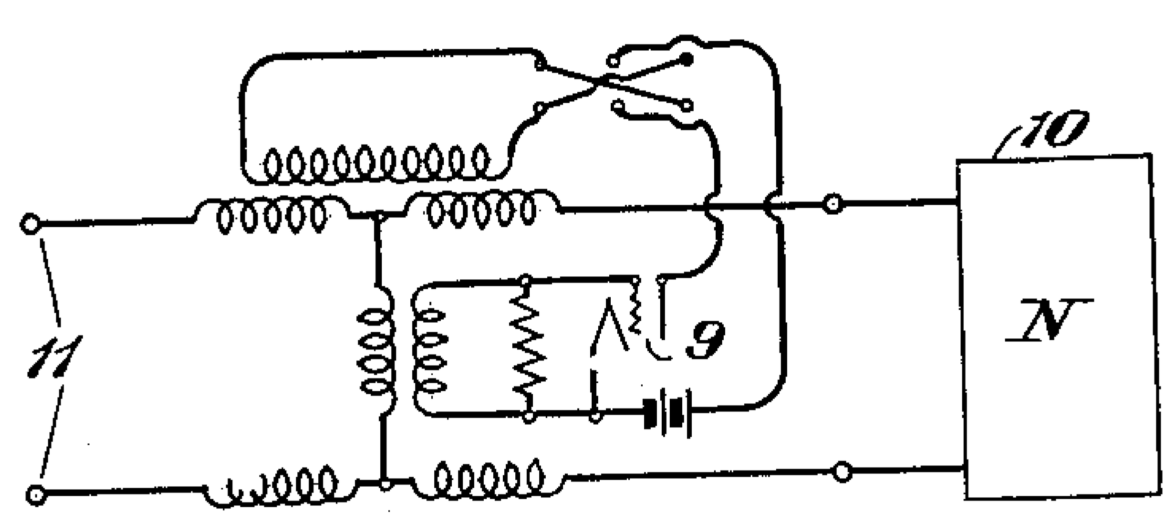


Fig. 7

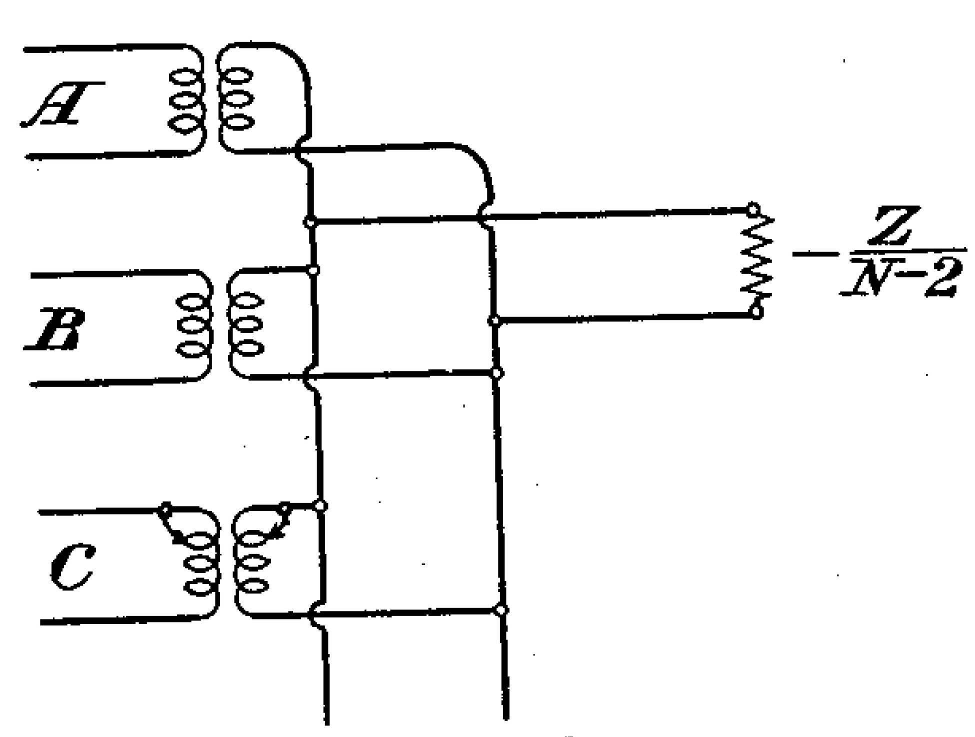


Fig. 8

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MULTIWAY CONNECTION FOR SIGNALING CIRCUITS

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Application September 3, 1931. Serial No. 561,076

10 Claims. (Cl. 178—44)

This invention relates to a multi-way connection for signaling circuits, and more particularly to circuits in which a plurality of branches or sections are connected together in parallel or in series.

One object of this invention is to provide means by which the echo or reflection effects which ordinarily occur in such connections shall be eliminated. A further object is to provide means by which in such connections there shall be no transmission losses, and still a further object is a combination of the two mentioned above in accordance with which neither reflection effects nor transmission losses shall occur in passing from any one of the group of interconnected circuits into any other or others of the group. Two forms of connection will be dealt with in this invention, the one in which several circuits are connected in parallel and the one in which they are connected in series.

To carry out the objects of my invention, I make use of negative resistances, of which I have disclosed and described certain types in my Patent No. 1,776,310, September 23, 1930 and in an article by me in The Bell System Technical Journal of July, 1931. By proper choice of the type of negative impedance or resistance, and by proper association with the lines to be connected, the impedance as seen looking from any one line or section into the remaining lines is rendered the same as that of the one line, thus eliminating reflection losses. At the same time, in view of the ability of the negative resistances to supply power, that is their characteristic of being active rather than passive networks, the transmission losses which would otherwise appear in connection with any one circuit to which signals are being transmitted will be reduced, even to the zero point.

The invention will be better understood by reference to the following specification and accompanying drawing in which Figure 1 shows the circuit for a plurality of circuits connected in parallel; Fig. 2 is for the case of circuits connected in series; Figs. 3 and 4 show schematic representations of two types of negative resistance; Figs. 5 and 6 show specific forms which the negative resistances of Figs. 3 and 4 may take on; Fig. 7 shows still another form of negative resistance; and Fig. 8 shows a modification of the circuit of Fig. 1.

Referring more specifically to Fig. 1, there are shown a plurality of circuits A, B and C which are to be joined in parallel such that signals originating in any one line or section will be supplied to each and all of the other sections. For simplicity we will at present assume that these lines are all identical in impedance, although this restriction may be removed in manners hereinafter described. With the circuits thus connected in parallel, it is evident that on looking from the junction point into the line A, from which signals may be assumed to emanate, there will be seen an impedance Z, whereas upon looking in the other direction there is seen an impedance given by

$$\frac{Z}{N-1}$$

where N is the number of signaling circuits to be joined. Thus, for signals coming from the line A, there will be reflection losses at the junction and there will be at the same time large transmission loss so far as any one of the other circuits are concerned in view of the fact that they must share the power.

To overcome this condition, I connect across the junction line, as indicated in Fig. 1, resistance impedance which has a negative value, and for the particular circuit this negative resistance is adjusted to a value of

$$\frac{-Z}{N-2}$$

where Z is the average impedance of the separate working circuits. A negative resistance of this value is just sufficient to give a smooth line termination to each of the sections, at least if they are of equal impedance; that is, there are no echoes due to reflections at the junction for signals coming from any one of the sections. This is readily seen, for if there are N circuits all of equal impedance Z, then if one looks from the junction of circuit A into the remaining circuits in parallel, the impedance as seen is given by

$$\frac{1}{z}=\frac{1}{Z_1}+\frac{1}{Z_2}+\cdots\frac{1}{Z_{N-1}}-\frac{N-2}{Z}=\frac{N-1}{Z}-\frac{N-2}{Z}=\frac{1}{Z}.$$

Furthermore, similar calculations show that the signaling current flowing from any one circuit, such as A, into each and all of the other circuits is equal to the current in the originating branch. Since each and all of the $N-1$ networks are to be supplied with current, it is evident that there must be a source to supply the necessary power. This the negative resistance does in the manner as explained in my patent cited above, and to such an extent as to just make up the loss due to the bridged connection so transmission takes place from any circuit into any other circuit without transmission loss. It is to be pointed out that the attainment of such a result from ordinary vacuum tube amplifying circuits is a difficult matter unless such amplifiers be so connected internally as to take on the characteristics of negative resistances rather than simple amplifiers whereupon, of course, the arrangement becomes equivalent to the one herein described.

Fig. 2 shows a circuit in which the various lines are connected in series, and while this series connection may be a conductive one I prefer to make it through transformers, as shown. Here, again, there are no reflection losses if the negative resistance takes on a value of $-(N-2)Z$, where Z is the average impedance of the working circuits. Thus, if one looks from the line A, whose impedance is Z, into the remainder of the circuit, he sees an impedance given by

$$z=Z_1+Z_2+\ldots Z_{N-1}-(N-2)Z=Z$$

Also, the current flowing in these lines taken in series is the same as that in the line A. Evidently, again, the E. M. F. to yield this current has its source in the negative resistance.

The type of resistance to be used is one of importance in order that the circuits may be stable in operation. Thus, in Fig. 1 I make use of a negative resistance which I have designated as the shunt type, whereas in Fig. 2 I make use of the series type. These types are shown diagrammatically in Figs. 3 and 4, and their respective characteristics have been set forth in detail in my patent cited above. One form which these may take on is shown in Figs. 5 and 6, respectively, and it will be noted that they make use of vacuum tube amplifiers with certain feed-back connections, whereupon their behavior is more properly described as negative resistances.

Still another form these negative resistances may take on is shown in Fig. 7 which, it will be observed, simulates the connections of a 21-type repeater circuit. In this Fig. 7 the well known hybrid coil is shown with a three-element amplifier tube 9 and a network 10 adjusted to appropriate value. If the network 10 has an impedance equal to that seen looking out from the terminals at 11, then power will be supplied to both the network 10 and to the line coming in at 11, and the circuit behaves like a two-terminal element exhibiting the properties of a negative resistance. An important property of this circuit of Fig. 7 is that by changing the poling of either the input coil or the output coil connected with the tube 9, the circuit may be changed from a negative resistance showing shunt characteristics to one showing series characteristics, and in applying this device to the circuits of Figs. 1 or 2 it is necessary to use that connection which is appropriate.

I have thus far implied that the negative resistances are pure resistances, and in many cases it would be sufficient to have them as pure resistances. In this case, of course, it would be understood that there would be some reflection at the junction if the lines or sections are not pure resistances in themselves. If these reflections become larger than desired, it would be possible to introduce reactive elements such as Z' of Fig. 2 with the negative resistances to secure a more perfect simulation of the negative of the line impedance. For this purpose any of the means now well known in the art for annulling reactance may be used.

In some cases where a plurality of lines or sections of the kind described are arranged for parallel or series connection, it occurs that at any one time only a limited number of the sections are to be connected. To provide for this greater flexibility in the circuit set-up, while still retaining the balanced conditions described above, means may be provided such as switches or jacks so that the different circuits may be connected to the junction or disconnected, at will. Such devices should be so arranged that when any circuit is disconnected, a network having the same impedance as the circuit is substituted for it as shown in the C circuit of Fig. 1. In this way any number of circuits less than N may be interconnected without disturbing the arrangement or adjustment of the apparatus at the junction.

Numerous variations may be made in my invention as I have thus far described it, and it is to be understood that these may be made without departing from the spirit of my invention. For example, in Fig. 1 it would be quite possible to connect the lines A, B and C to the common junction point through transformers, as shown in Fig. 8. Such an arrangement would be highly advantageous in certain cases. For instance, if the lines A, B, C, etc. do not have the same impedance characteristic, they may be brought to the same impedance as seen from the junction point by using step-up or step-down transformers of appropriate ratio. Also, it will be understood that instead of using transformers to bring about this matching of impedances, it might be accomplished by any other type of network for such purpose now well known in the art. Also, while the invention was described in terms of equal impedance for each of the lines, it will be understood that even though this may be nominally true, there will be small variations which cumulatively may be bothersome. There might be some question in this case as to what value to assign the negative resistance, but it will be obvious that the value of Z to be chosen should be at or near the average impedance of the N sections.

What is claimed is:

1. In a multi-way circuit, a plurality of N working circuits connected in circuit together and a negative impedance also connected in the circuit, the latter being adjusted in magnitude to neutralize the impedances of $N-2$ of the working circuits.

2. In a multi-way circuit, a plurality of N working circuits connected in series and a negative impedance also connected in series, the latter being adjusted in magnitude to the sum of the impedances of the working circuits minus twice the average of the impedances of the circuits.

3. In a multi-way circuit, a plurality of N working circuits connected in parallel and a negative resistance associated therewith so that the impedance as seen looking from any one line is equal to the impedance of that line.

4. In a multi-way circuit, a plurality of N working circuits connected in series and a negative impedance associated therewith so that the impedance as seen looking from any one line is equal to the impedance of that line.

5. In a multi-way circuit, a plurality of N working circuits associated with each other and an active network associated therewith to neutralize impedance to such an extent that there are no reflection losses or transmission losses for the plurality of circuits.

6. In a multi-way circuit, a plurality of N working circuits connected in parallel at a common junction point and means associated therewith to

neutralize impedance to such an extent that there are no reflection losses or transmission losses at the junction of the plurality of circuits.

7. In a multi-way circuit, a plurality of N working circuits connected in series and means associated therewith to neutralize impedance to such an extent that there are no reflection losses or transmission losses for the plurality of circuits.

8. In a multi-way circuit, a plurality of N working circuits of equal impedance Z connected in parallel and a negative impedance of value

$$\frac{Z}{N-2}$$

connected in parallel at the common junction.

9. In a multi-way circuit, a plurality of N working circuits of equal impedance Z connected in series and a negative impedance of value $(N-2)Z$ connected in series therewith.

10. In a multi-way circuit, a plurality of N working circuits of unequal impedance connected in parallel at a common junction point, a transformer in each line prior to the connection and of such ratios as to bring all the lines to the same impedance Z and a negative impedance of shunt characteristics connected in parallel at the junction point, said resistance being adjusted to a value

$$\frac{Z}{N-2}$$

GEORGE CRISSON.