

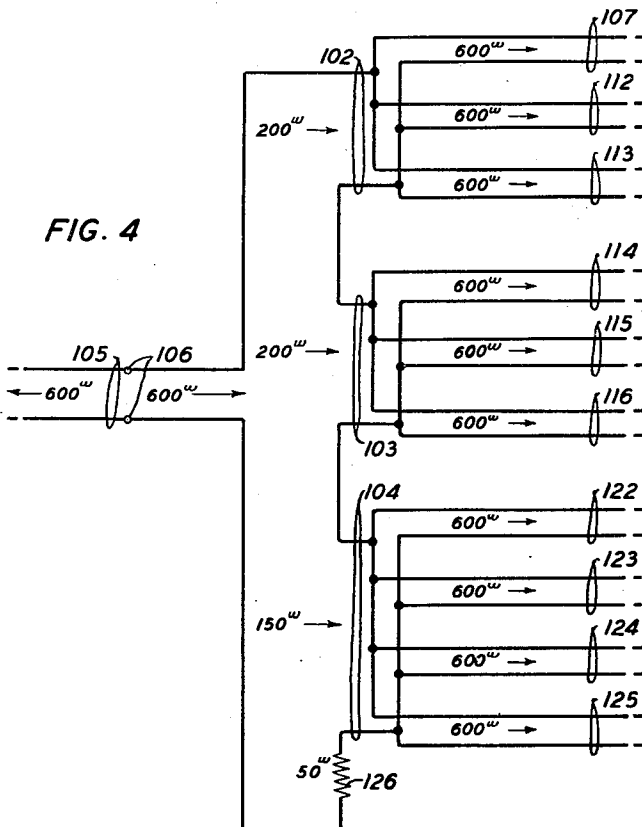
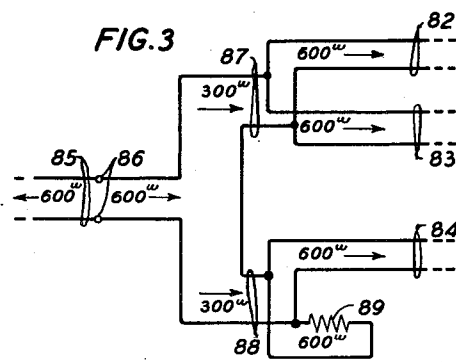
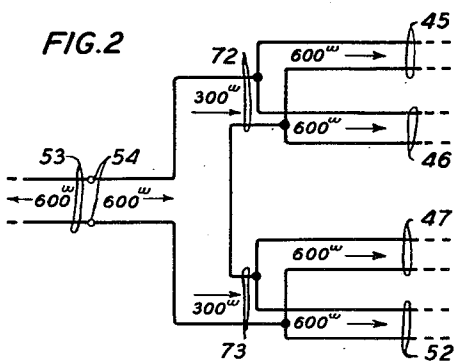
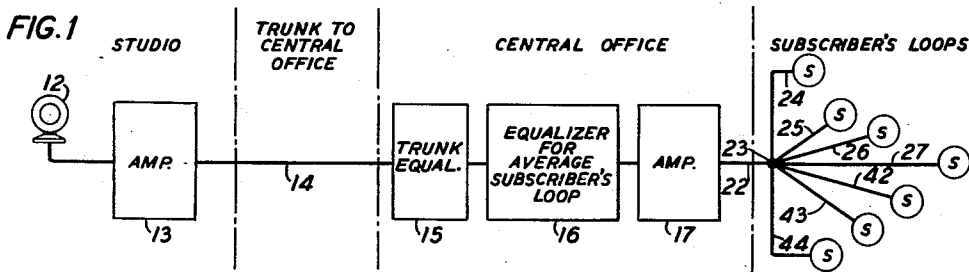
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TRANSMISSION SYSTEM

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TRANSMISSION SYSTEM

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This invention relates to a transmission system and more particularly to a transmission system in which a main transmission line is connected to a plurality of branch lines, transmission being from the main line into the branch lines.

An object of the invention is the prevention, or avoidance, at points in a transmission system at which a main line is connected to a plurality of branch lines of any condition that might result in impairment of the quality or reduction of energy of signals transmitted by the system.

A more specific object of the invention is the prevention, or avoidance, of reflection at junction points in a transmission system.

In certain types of transmission systems it is desirable to connect a number of branch lines to a main line, or main stem as it may be termed, in order that the signals transmitted over the main stem may be received by each of the branches.

A good example of such a system, and the one selected for illustration of applicant's invention, is a wire broadcasting system where we have, as a rule, at a number of points in the main trunk lines, a plurality of subscribers' loops branched off therefrom. The number of loops connected at any one junction point may vary, of course, according to the demand for the program service.

A feature of the invention is means whereby various numbers of branches may be connected at a point in a main stem without causing reflection; the number of branches may be, for example, four or some other number which is a perfect square or it may be three or some other number not a perfect square. The arrangement of the invention not only avoids reflection at the junction point but at the same time transfers the maximum possible energy from the main stem to the branches.

In accordance with a specific embodiment of the invention, a series-parallel connection scheme is followed wherein a certain number of groups of branches, each group comprising a certain number of branch lines in parallel, are connected in series with the main stem. The exact arrangement varies in accordance with the number of branch lines; in certain instances a resistance is used to simulate a branch line while in other instances a resistance is connected in series with the groups of branches.

A complete understanding of the arrangements contemplated by the invention and appreciation of the desirable features thereof may be had by consideration of the following detailed description in connection with the annexed drawing in which:

Fig. 1 illustrates schematically a wire broadcasting system, a plurality of branch lines (subscribers' loops) being shown connected at a point to a main line;

Fig. 2 illustrates the arrangement contemplated by the invention in instances where the number of branch lines to be connected to the main stem is a perfect square;

Fig. 3 illustrates the arrangement contemplated by the invention in instances where the number of branches to be connected to the main stem is in accordance with the equation

$$m > n \geq (m - \sqrt{m})$$

where m is a perfect square and n is the number of branches; and

Fig. 4 illustrates the arrangement contemplated by the invention in instances where the number of branches to be connected to the main stem is in accordance with the equation

$$m_1 < n < (m_2 - \sqrt{m_2})$$

where m_1 and m_2 are two successive numbers in the ascending table of perfect squares and n is the number of branches.

Referring now to Fig. 1, there is illustrated in schematic manner a system whereby a program originating at a central studio may be transmitted by wire to a plurality of telephone subscribers. (The details of systems of the general nature have previously been published and will not be given here; Bascom et al. Patent 1,685,835 describes one form of wire broadcasting system.) The programs to be distributed originate at a central studio where they are picked up by microphone 12, pass through amplifier 13 and out over trunk 14 to a central office where the programs are amplified and distributed to the subscribers over the subscribers' loops, suitable receivers being provided on the subscribers' premises.

It is usual to provide at the central office an equalizer, such as equalizer 15, which corrects for the frequency distortion introduced by the circuit from the central studio to the central office. There may be provided also, at this point, means for pre-equalizing the subscribers' loops, that is, compensating in advance for frequency distortion introduced by the subscribers' loops. (The pre-equalization idea in itself is well known and will not be described in detail here; Hamilton Patent 1,871,986 and Affel Patent 1,819,054 disclose pre-equalizer arrangements.) In this instance, a single equalizer 16 is provided which is designed to correct for the average length of the seven loops illustrated. While such an arrange-

ment does not, of course, correct exactly the frequency distortion of each of the loops, it has been found that over-all correction is quite satisfactory and the arrangement is, of course, much more economical than that utilizing a separate equalizer for each loop. If a more exact correction be desired, however, an equalizer may be provided for each loop or at least for each group of loops; one group may comprise the "short" loops, another the "long" loops and a third the "medium" loops.

After passing through equalizer 16, the program currents are amplified by amplifier 17 and transmitted over a main trunk 22 to junction point 23 at which point seven subscribers' loops 24, 25, 26, 27, 42, 43 and 44, are connected to the main trunk 22. Here the program currents are transmitted into these various branch lines and thence to the subscribers' premises. In certain instances a branch line may be connected in turn to sub-branches, in fact when desirable this process of branching may be repeated several times.

By reference now to the other figures of the drawing the application of the arrangements contemplated by the invention to the problem of connecting various numbers of branch lines (such as the subscribers' loops of Fig. 1) will be explained. It will be evident, of course, that similar arrangements would be followed in instances where the branch lines are connected in turn to sub-branches.

Referring first to Fig. 2, four branch lines 45, 46, 47 and 52, are shown connected to main stem 53 at junction points 54, four being taken as a number representative of the first general case to be explained, that is, the general case where n is a perfect square, n being the number of branch lines. It is assumed that the characteristic impedance Z_0 of each branch line is equal to that of the main stem, 600 ohms resistance being taken as a representative value of Z_0 . Now it is obvious that if reflection is to be avoided at junction points 54, the impedance looking into the main stem at this point should be the same as that looking into the branches. This relationship does result from the arrangement illustrated, the 600 Ω characteristic impedance of the main stem being exactly matched or balanced by the 600 Ω impedance of the connected branches. This latter value represents, of course, the sum of the 300 Ω impedance of group 72 and the 300 Ω impedance of group 73, each group comprising two 600 Ω lines connected in parallel.

In general, applicant has determined that in instances where n is a perfect square, the branch lines should be divided into

$$\sqrt{n}$$

groups, each group comprising

$$\sqrt{n}$$

lines in parallel, and the

$$\sqrt{n}$$

groups connected in series with the main line. That is, with

$$n=4$$

as in Fig. 2, the four branches are divided into

$$\sqrt{4}$$

or two groups, each group comprising

$$\sqrt{4}$$

or two lines, the two groups being connected in series with the main stem.

Taking another perfect square, sixteen, for further illustration, here we would divide the sixteen branch lines into

$$\sqrt{16}$$

or four lines, and connect the four groups in series with the main line. In this instance again and, indeed, in all instances where n is a perfect square, the arrangement results in a perfect matching of the characteristic impedance of the main stem and that of the branch lines.

Referring now to Fig. 3, three branch lines 82, 83 and 84 are shown connected to main stem 85 at junction points 86. Three is here taken as representative of the general case to be next explained, that is, the case where the value of n (number of branch lines) is such that

$$m > n \geq (m - \sqrt{m})$$

where m is a perfect square. Values of n thus taken care of are:

m	n
4	3, 2
9	8, 7, 6
16	15, 14, 13, 12

etc.

In general, this type of connection is the same as that described above in cases where n is a perfect square except for the fact that one branch line in any one of the groups is replaced by a dummy line or resistance. That is, the arrangement of Fig. 3 is the same as that of Fig. 2, so far as group 87 is concerned; with respect to group 88, however, resistance 89 has been added in parallel with line 84 in order to arrive at the desired group impedance of 300 Ω . With this arrangement we have, as before, an exact balance between the impedance at points 86 looking into main stem 85 and the impedance looking into the branch lines.

In general, therefore, where the value of n is such that

$$m > n \geq (m - \sqrt{m})$$

where m is a perfect square, we proceed as if n were a perfect square and utilize a resistance or, if necessary, a complex impedance, as a dummy branch line in order to complete one of the groups of branch lines, the impedance of the resistance being, of course, the same as that of the branch lines.

Referring now to Fig. 4, three groups of branch lines, 102, 103 and 104, are shown connected in series with main line 105 at junction points 106. Group 102 comprises three branch lines, 107, 112 and 113 connected in parallel, group 103 comprises three branch lines 114, 115 and 116, connected in parallel while group 104 comprises four branch lines 122, 123, 124 and 125, connected in parallel. The value of n here illustrated, that is, ten, is taken as representative of the third general case to be described, that is, the general case where the value of n is such that

$$m_1 < n < (m_2 - \sqrt{m_2})$$

where m_1 and m_2 are two successive numbers in the ascending table of perfect squares.

In this instance it will be apparent that, so far as the groups of branch lines are concerned, the impedance looking toward the branch lines from points 106 is 550 Ω ; the impedance looking into the

main stem, however, is 600 Ω as before. In order to achieve the desired balance, resistance 126 is connected in series with the groups of lines; the 50 Ω impedance of the resistance when added to the 550 Ω impedance of the groups of lines being sufficient to just balance the impedance looking into the main stem.

In general, applicant has determined that in cases where the value of n is such that

$$m_1 < n < (m_2 - \sqrt{m_2})$$

where m_1 and m_2 are two successive numbers in the ascending table of perfect squares, the desired impedance balance may be obtained by dividing the branch lines into

$$\sqrt{m_1}$$

groups and connecting these groups in series, each group comprising

$$\sqrt{m_1}$$

or

$$\sqrt{m_2}$$

lines in parallel, the size of the groups being so chosen as to obtain an impedance equal to or less than the desired value Z_0 . If the resulting impedance value be less than Z_0 , a series resistance of proper value is introduced, as illustrated in Fig. 4.

To illustrate further, we have in the arrangement disclosed in Fig. 4, $n=10$, $m_1=9$ and $m_2=16$. The n branch lines are, therefore, divided into

$$\sqrt{9}$$

or three groups, two of which consist of

$$\sqrt{9}$$

or three lines, and the third of which consists of

$$\sqrt{16}$$

or four lines. As the resulting impedance is less than Z_0 , we add a resistance in series with the groups of lines of sufficient value to build the impedance out to a value of Z_0 .

As a further illustration, let us assume that $n=17$, in which case $m_1=16$ and $m_2=25$. Our 17 branch lines would, therefore, be divided into

$$\sqrt{16}$$

or four groups, three of which would include four lines in parallel and the fourth of which would include five lines in parallel. As the resulting impedance when these groups are connected in series would be 570 Ω , a building-out resistance of 30 Ω would be included in the series connection to bring the total impedance to the desired value of 600 Ω . Had n been equal to 18, we would then have four groups, two of which would consist of four lines in parallel and two of which would consist of five lines in parallel, a building-out resistance of 60 Ω being utilized to bring the total impedance to the desired value of 600 Ω .

It may be found desirable under certain conditions to connect a resistance of relatively small value in series with each branch line as a protective measure so that a short circuit occurring in one line will not affect others connected in parallel therewith. In such instance, a compensating resistance should be shunted across the parallel connection in order to preserve the balanced impedance relationship of the network. The use of protective series resistances of this general nature is referred to in Hamilton et al. Patent 1,900,106, issued March 7, 1933.

In the cases described above, it has been assumed that the characteristic impedance of each branch line is the same as that of the main stem. It will be evident, however, that a similar arrangement may be utilized to advantage in certain other cases when the characteristic impedance of the main stem and that of the branches are not equal. For example, in the instance of the arrangement of Fig. 2, it will be apparent that, had the impedance of each branch been twice that of the main stem, we could then form our groups of twice as many branch lines connected in parallel.

If desirable, other types of branching networks may, of course, be utilized in the transmission system in conjunction with the impedance matching scheme of the present invention. For example, a high impedance bridge connection may be used; while such a connection scheme involves a considerable loss so far as the bridged circuit is concerned, it permits the main stem to extend on with substantially no loss. It may be found desirable under certain conditions to utilize high impedance bridge connections near the central office and impedance matching connections farther out on the system.

While certain specific embodiments of the invention have been selected for detailed description, the invention is not, of course, limited in its application to the embodiments described. The embodiments which have been described should be taken as illustrative rather than restrictive thereof.

What is claimed is:

1. In combination, a main stem having a characteristic impedance of value Z_0 and a plurality of branch lines each having a characteristic impedance of value Z_0 , said branch lines being divided into a plurality of groups each of which comprises a number of branch lines connected in parallel, all of said groups being connected in series to the main stem, the number of branch lines in each group and the number of groups being such that the sum of the impedances of all of the groups is equal to Z_0 .

2. In combination, a main stem having a characteristic impedance of value Z_0 a plurality of branch lines each having a characteristic impedance of value Z_0 and an additional impedance element, said branch lines being divided into a plurality of groups each of which comprises a number of branch lines connected in parallel, all of said groups and said additional impedance element being connected in series to the main stem, the value of said additional impedance being such that the sum of the impedances of all of said groups and of said additional element is equal to Z_0 .

3. The method of joining a main stem having a characteristic impedance of value Z_0 and n branch lines each having a characteristic impedance of value Z_0 , n being a perfect square, which comprises dividing said branch lines into

$$\sqrt{n}$$

groups, each of which comprises

$$\sqrt{n}$$

branch lines in parallel, and connecting said

$$\sqrt{n}$$

groups in series to said main stem.

4. The method of joining a main stem having a characteristic impedance of value Z_0 and n branch lines, each of which has a characteristic

impedance of value Z_0 , the value of n being such that

$$m > n \geq (m - \sqrt{m})$$

- 5 where m is a perfect square, which comprises dividing the branch lines into

$$\sqrt{m}$$

groups,

$$\sqrt{m} - 1$$

- 10 of which groups comprises

$$\sqrt{m}$$

- lines connected in parallel and one of which
15 groups comprises one or more, but less than

$$\sqrt{m}$$

- lines and a resistance connected in parallel, and
20 connecting all of said groups in series to the main stem, the value of said resistance being such that the impedance of said last-mentioned group is the same as that of the other groups, the sum of the impedances of all of said groups being of a value Z_0 .

- 25 5. The method of joining a main stem having a characteristic impedance of value Z_0 and n branch lines, each of which has a characteristic impedance of value Z_0 , the value of n being such that

30
$$m_1 < n < (m_2 - \sqrt{m_2})$$

where m_1 and m_2 are successive numbers in the ascending table of perfect squares, which comprises dividing said branch lines into

- 35
$$\sqrt{m_1}$$

groups, connecting said groups in series to said main stem, certain of said groups comprising

- 40
$$\sqrt{m_1}$$

branch lines connected in parallel and others of said groups comprising

$$\sqrt{m_2}$$

- 45 branch lines connected in parallel, the size of the groups being so chosen that the sum of the impedances of all the groups will be equal to Z_0 , or as nearly equal to Z_0 as mathematically possible and in no case greater than Z_0 , and, if
50 said sum be less than Z_0 , connecting a resistance in series with said groups of sufficient value that the sum of the impedance of said groups and said resistance will be equal to Z_0 .

6. The method of joining a main stem having
55 a characteristic impedance of value Z_0 and a plurality of branch lines each having a characteristic impedance of value Z_0 which comprises dividing said branch lines into a plurality of groups, each group comprising a plurality of
60 branch lines connected in parallel, connecting all of said groups in series to said main stem, the number of parallel connected lines in each group being such that the sum of the impedance of all the groups is less than Z_0 , and connecting
65 a resistance in series with said groups and said main stem of sufficient value that the sum of the impedances of all of said groups and of said resistance is equal to Z_0 .

7. The method of accomplishing a balanced
70 impedance coupling between a main stem and a plurality of branch lines, the characteristic impedance of all the branch lines being of the

same value, which comprises assembling said branch lines into a plurality of groups, each group comprising a plurality of branch lines connected in parallel whereby the over-all impedance of each group is less than that of a single branch line, and connecting all of said groups in series to the main stem, the number and size of the groups being such that the sum of the over-all impedances of all of said groups is equal to the characteristic impedance of the 10 main stem.

8. In combination, a main stem having a characteristic impedance of value Z_0 , a plurality of branch lines each having a characteristic impedance of value Z_0 and an additional impedance element, said branch lines being divided into a plurality of groups each of which comprises a number of branch lines connected in parallel, said additional impedance element being
20 connected in parallel with the lines of one of said groups, all of said groups being connected in series to the main stem, the value of said additional impedance being such that the sum of the impedances of all of said groups is equal to Z_0 .

9. The method of joining a main stem having a characteristic impedance of value Z_0 and a plurality of branch lines each having a characteristic impedance of value Z_0 which comprises dividing said branch lines into a plurality of
30 groups, each group comprising a plurality of lines connected in parallel, the number of lines in each group being the same in cases where the total number of branch lines is such that this arrangement is mathematically possible, and
35 if the arrangement is not possible, one of the groups comprising a lesser number of branch lines and an additional impedance connected in parallel, and connecting all of said groups in series to the main stem, the sum of the impedances of all of said groups being equal to Z_0 or as nearly equal to Z_0 as is mathematically possible in view of the number of branch lines and in no case greater than Z_0 , an additional impedance being connected in series with the groups
45 in cases where the sum of the impedances of all of said groups is less than Z_0 , the value of said additional impedance being such that the sum of the impedances of all of said groups and of said additional impedance is of a value Z_0 .

10. The method of avoiding reflection at a junction point between a main stem having a characteristic impedance of value Z_0 and a plurality of branch lines each having a characteristic impedance of value Z_0 which comprises dividing
55 said branch lines into a plurality of groups, at least one of said groups comprising a plurality of lines connected in parallel, and connecting all of said groups in series to the main stem, the total impedance connected in series to the main stem being of a value Z_0 .

11. In combination, a main stem having a characteristic impedance of value Z_0 and a plurality of branch lines each having a characteristic impedance of value Z_0 , said branch lines being divided into a plurality of groups at least one of which comprises a plurality of lines connected in parallel, all of said groups being connected in series to the main stem, the total impedance connected in series to the main stem
70 being of value Z_0 .

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