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A. B. CLARK ET AL

TRANSMISSION CIRCUITS

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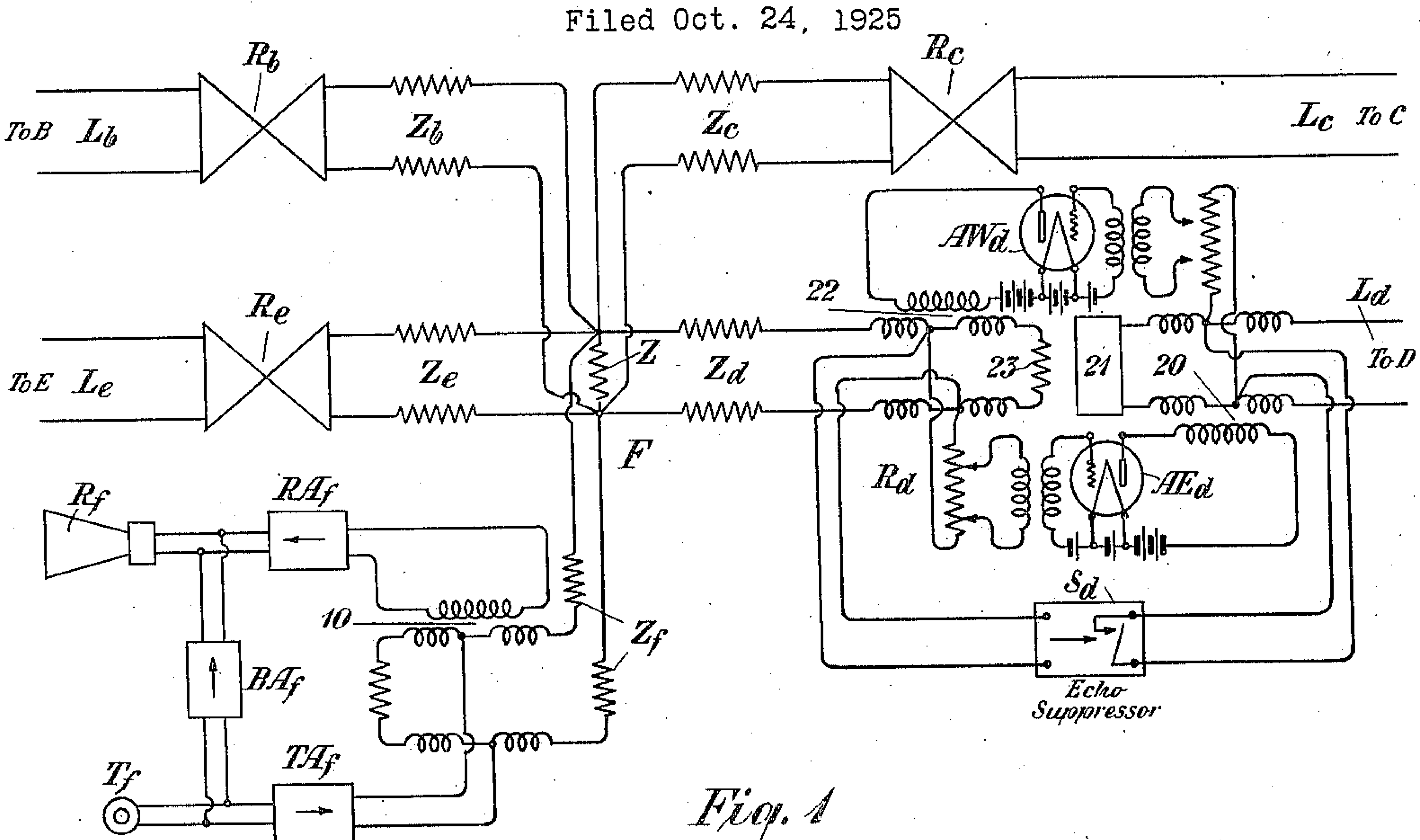

Fig. 1

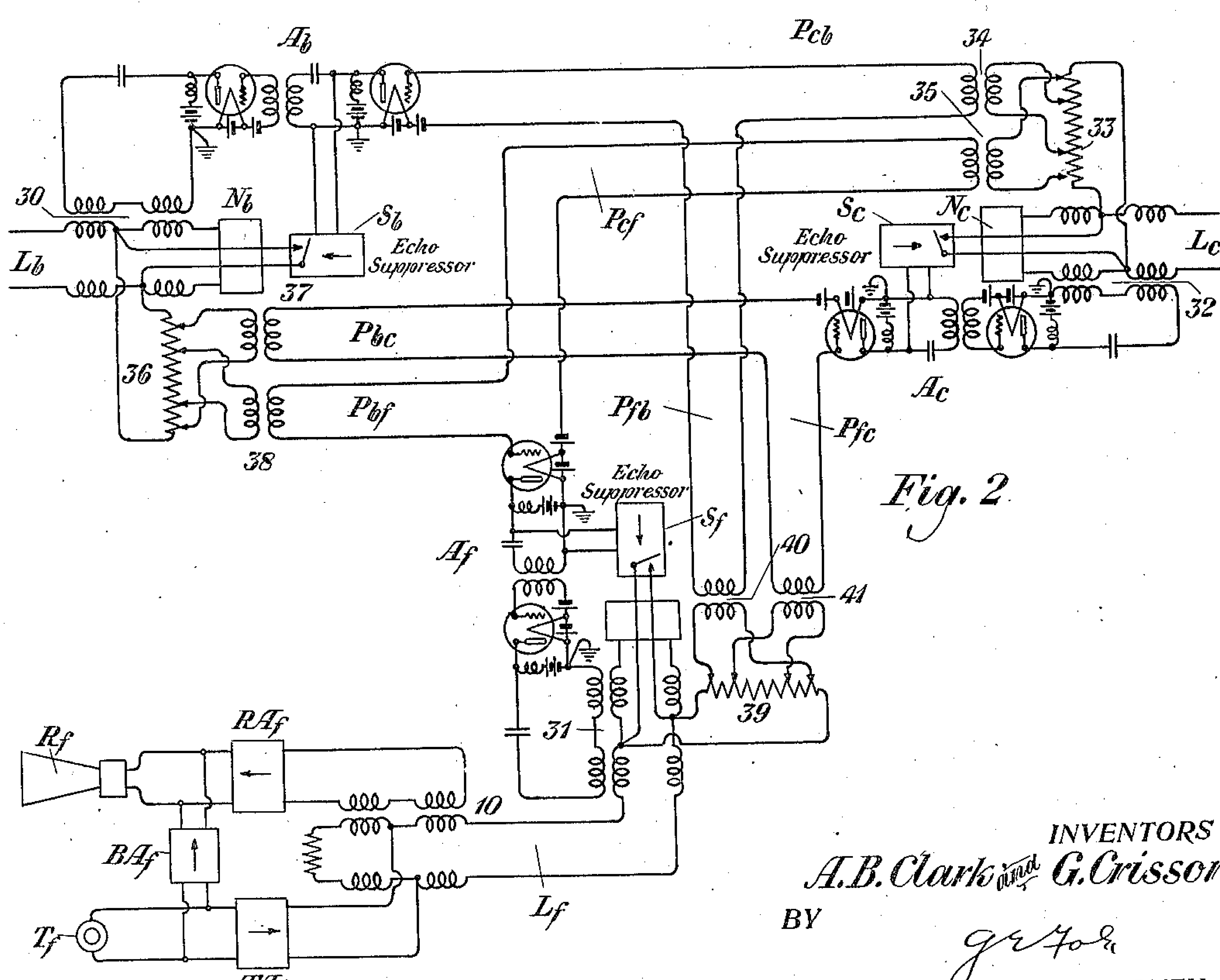

Fig. 2

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TRANSMISSION CIRCUITS.

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This invention relates to transmission systems, and more particularly to transmission sytems adapted for interconnecting public address systems or radio broadcasting stations or the like, to enable a plurality of widely separated audiences to hear speech or music presented before either.

Where a plurality of public address systems or radio broadcasting stations are interconnected so that a program presented at any station may be heard at all of the others, difficulty arises form the fact that the audience at a particular station will hear the program from the local transmitter better than programs transmitted from distant transmitters. This arises from the fact that a transmission loss inevitably occurs in transmitting from the distant to a particular local station. Heretofore, it has been proposed to provide a special interconnecting arrangement between each receiver and its local transmitter to regulate the volume transmitted, but such arrangements are not satisfactory where the transmission loss from distant points is determined by echo effects. It is therefore one of the objects of the present invention to provide a circuit arrangement for interconnecting a plurality of public address systems or radio broadcasting stations in such a manner that a local audience will hear the program from the local transmitter with substantially the same volume as that from a distant transmitter notwithstanding echo effects. Another object of the invention is to provide an arrangement by which the several transmission circuits may be interconnected through a common station at which suitable provision will be made for equalizing the transmission to all of the stations and for overcoming echo effects.

These and other objects of the invention are attained by means of the arrangements set forth in the following detailed description and illustrated in the accompanying drawings. Figures 1 and 2 of which illustrate two forms of circuit arrangements embodying the invention.

Before proceeding to a description of the invention, some explanation is desirable of the problem that is involved in interconnecting two or more public address systems or broadcasting stations. If we assume a transmission line interconnecting two distant points, and at each station a terminal arrangement comprising a transmitter connected to the line by way of a branch including an amplifier and a loud speaking receiver or other device connected to the line through another branch, including an amplifier, it will be apparent that the volume of sound emitted by the loud speaker at a given station will be greater when the local transmitter is operated than when the distant transmitter is operated. This difference between the transmission will be equal to the transmission loss in the line.

Where the minimum net loss in the transmission line is not limited by talker echo effects, the terminal stations of the lines may be arranged so that the transmitting and receiving branch are interconnected with the line through a hybrid coil and balancing network, as shown at 10 in Fig. 1. The local transmitter and receiver may be made substantially conjugate with respect to each other by this arrangement so that the local transmitter does not transmit to the local receiver through the common connection to the line. If then a by-pass connection, including an amplifier BA_t, is provided, the transmission between the transmitter and the loud speaker may be determined by the amplifier BA_t. In the absence of echo effects, the amplifier BA_t may be adjusted to render the transmission from the local transmitter to the local receiver equal to that from the distant transmitter to the local receiver.

In order to understand how echo effects bear on the equalization of volume, it is desirable to say a word as to the nature of echoes. In general, echoes are of two kinds —talker echoes and listener echoes. When the voice currents originating at a transmitter are transmitted to a distant point and there encounter impedance irregularities, the currents reflected back to the local receiver are known as talker echo currents. If, however, the voice currents, after being reflected back once encounter another impedance irregularity and are again reflected in the direction of original transmission, the currents thus transmitted to the distant receiver are known as listener echoes.

Now suppose we have a transmission line with a number of two-way repeaters located at suitable points, and the gain of one of the two-way repeaters in each direction is raised one unit. Obviously, the direct transmission over the line is only raised one unit. Talker echoes, however, pass through this repeater twice, once in the direction of original transmission and once when they are reflected back to the local receiver. Listener echoes, on the other hand, will pass through the repeater three times, for not only are they reflected back towards the local receiver, but they are again reflected through the repeater in the original direction. Obviously, then, the echo currents are amplified to a greater extent than the direct transmission, and as we attempt to reduce the transmission loss of the line by increasing the gain of the amplifiers, a point is reached where the echo currents have been so amplified as compared with the direct transmission that the situation becomes intolerable. Thus, it will be seen that echo currents become a limiting factor in determining the transmission equivalent of the circuit, and limit the gain to which the repeaters may be set to a point below singing. Depending on the electrical characteristics of the line, its physical make-up, etc., in some instances talker echoes limit the gain of the repeaters in the line and in other instances listener echoes limit the gain.

When the line connecting two stations is of such type that its minimum net loss is limited by talker echoes, the circuit arrangement just described does not permit the equalization of volumes because the hybrid coil does not keep the echoes from the line out of the receiver. The talker echoes coming from the line will be heard in the receiver with the same volume as if the transmitter and receiver branch were directly connected to the line in parallel without the by-pass arrangement. Consequently, the by-pass amplifier BA_t must be adjusted to give at least the same volume of sound from the transmitter as in the case where the transmitter and receiver are directly connected to the line. That this is so will be clear if we consider that the amplifier BA_t adjusted so that the same volume of sound is heard in the receiver R_t from the local transmitter T_t as would be the case where the transmitter and receiver circuits are directly connected to the line. If, under these conditions, the amplifiers in the assumed transmission lines to connect two distant stations are adjusted until talker echoes limit further increase in the gain of the repeaters, it will be evident that the gain of the amplifier BA_t can not be cut down without reducing the signal as compared with the echoes. As this would be intolerable under the conditions just outlined, it is clear that the difference between the volumes of sound from the local transmitter and the distant transmitter is the same in both arrangements under the conditions where the minimum net loss is limited by talker echoes.

If the assumed transmission line is of such character that its minimum net los is determined by listener echoes or (by other causes than talker echoes) it would be possible to reduce the gain of the by-pass amplifier such as BA_t or increase the gain of the receiving amplifier such as RA_t until talker echoes prevent further changes. If there were no talker echoes present the arrangements employing the hybrid coil connection and the by-pass might be adjusted to produce a full equivalence between signals in the local transmitter and signals from the distant transmitter. If talker echoes are present, however, the equalizing adjustment can not proceed beyond the point at which the talker echoes effectively limit the gain.

In the foregoing discussion no consideration has been given to an additional difficulty which arises where more than two distant stations are interconnected. If we interconnect any considerable number of widely separated stations in such a manner as to furnish two-way transmission between any given station and all of the others, the transmission loss between different pairs of stations is in general different, so that the listener at one station does not receive the same volume from all of the other stations. The arrangements which are now about to be described provide means for overcoming not only the difficulty just stated but the difficulties due to echoes. To accomplish the latter result use is made of echo suppressors which eliminate or greatly reduce the echoes to secure a complete equalization. The transmission losses between stations can therefore be reduced and the listener enabled to hear the distant stations more loudly than would otherwise be possible. The equalization of the transmission loss between stations is accomplished by using the echo suppressors in combination with an interconnecting arrangement whereby a plurality of lines may be associated with each other for transmission between a station associated with any line and the stations of all the other lines. This interconnecting arrangement in the case of Fig. 1 may be a star-shaped system of lines radiating from a common point with an amplifier and echo suppressor in each branch of the star for equalizing transmission. In the case of Fig. 2 the interconnecting arrangement may comprise a multiple-way repeater, each repeater unit of which is provided with an echo suppressor.

Referring to Fig, 1, L_b, L_c, L_d and L_e designate transmission lines of any type extending from an interconnecting point F to distant stations B, C, D and E (not illustrated). These distant stations may be provided with transmitting and receiving equipment of any type. This equipment might be the ordinary telephone substation set, or a set comprising a high quality transmitter, loud speaking receiver and circuit connections involving a hybrid coil, balancing network and by-pass as already described. If a talking and listening station is to be provided at the central point F, it may be connected in by means of the hybrid coil 10, one-way amplifiers TA_f and RA_f, and by-pass amplifier BA_f arranged as already described.

A multiple-way artificial line built up of resistances is used to form the connection. This line is like the ordinary H-type of artificial line except that there is a pair of series resistances Z_b, Z_c, etc., for each of the several stations to be connected. These series resistances are all equal in value. There is also a shunt resistance Z, common to all the connections. By properly proportioning these resistances the multiple-way line can be made to present to each repeater, such as R_b, R_c, R_d and R_e, the impedance with which it is designed to work. These repeaters which are merely shown conventionally, except in the case of R_d, are all alike and have the same impedance. The star network introduces the same loss between any given repeater and any other repeater. The function of the repeater is of course, to adjust the transmission between the line with which it is associated and the star connection so that the over-all transmission from the terminal station to the star connection will be the same for all of the lines involved. It will be apparent from the nature of the star network that there is a certain minimum loss for which the network may be designed and built, this loss becoming greater as the number of branches increases.

The repeater R_d is shown in detail and comprises the usual amplifier AW_d for transmitting from east to west, and amplifier AE_d for transmitting from west to east, the amplifiers being provided with potentiometers as is usual for adjusting the gain. The amplifiers are connected to the terminal line L_d through a hybrid coil 20, a balancing network 21 of the usual type being provided to render the repeater branches conjugate. The repeater branches are also connected to the corresponding branch Z_d of the star netwark through a hybrid coil 22. The impedance of the star network may be accurately balanced by means of a simple resistance 23.

The repeaters R_b, R_c, etc., schematically indicated, are similar to the repeater R_d above described. The gain of each repeater is set so that equal net losses occur between each distant terminal station and the terminals of the artificial line. The net loss between any two stations is then the same and any station hears all of the other stations with equal volume. In the case of the local transmitter and receiver at the station F the volume is determined by the amplifiers TA_f and RA_f so that no special repeater as just described is necessary.

When transmission takes place from any station it enters the star network and goes out to all the other stations. Echoes then return from each of the other stations to the central point from which point the echoes pass through all of the stations including the transmitting station, so that the echoes may be heard by all stations. To prevent these echoes an echo suppressor is applied to each 22-repeater such as the repeater R_d. This echo suppressor is schematically indicated and may be of a well known type including a suitable amplifier and rectifier for amplifying and rectifiying voice currents and a relay for controlling a short circuit contact, the relay being operated by the rectified voice currents. As shown, the input of the echo suppressor S_d is connected to the midpoints of the hybrid coil 22, and the short-circuiting contacts are connected across the midpoints of the hybrid coil 20. If the impedance balance between the artificial line and the balancing resistance 23 is good enough to prevent false operation due to unbalanced currents when transmission originates at the station D, the echo suppressor S_d will not operate by currents originating at the station D and hence, there will be no necessity to provide a corresponding echo suppressor unit connected in the opposite direction and arranged to disable the echo suppressor unit S_d. The echo suppressor unit S_d is so connected that when transmission takes place from the interconnecting point out toward the station D, echoes from the terminal stations are prevented from coming back over the line L_d to the common point. In other words, talking currents coming from the star network to the repeater R_d operate the echo suppressor unit S_d and short circuit the midpoints of the hybrid coil 20. This does not prevent the amplified voice currents from passing through the amplifier AE_d to the line L_d. As this short circuit is connected directly across the input side of the amplifier AW_d, however, it does prevent voice currents or echo currents incoming over the line L_d

from passing through the amplifier AW_d to the star network.

Since all of the two-wire lines have these suppressors, no echoes return to the center and it is not necessary to provide equipment to prevent echoes going from the center over the two-wire lines. No suppressor is shown at the local set of the station F and none will be required unless the transmitter T_f is so placed as to be disturbed by sounds from the loud speaker R_f. If the echo suppressors at the central point, as above described, are not sufficient to secure the desired freedom from echoes and equality of transmission loss between the local and distant stations, still other two-wire suppressors may be used at suitable points at any or all of the two-wire lines. If, on the other hand, each two-wire line is supplied with one or more echo suppressors at intermediate points between its ends, the difficulty from echoes at the central point may be so small that echo suppressors need not be provided thereat. The arrangement shown, however, accomplishes the desired result with a minimum of echo suppressing apparatus, since only one-half of a complete suppressor equipment is required for each line.

An arrangement of connections involving the use of echo suppressors in connection with a multiple-way repeater is illustrated in Fig. 2. Here an amplifier A_b is provided for transmitting from the local line L_f or from the line L_c to the line L_b. The output of this amplifier is connected through the usual hybrid coil 30 to the line L_b. A similar amplifier A_f is connected through a hybrid coil 31 to the line L_f to take care of transmission from lines L_b and L_c. Likewise, a one-way amplifier A_c is connected through the hybrid coil 32 to the line L_c to take care of transmission from the lines L_b and L_f. An input potentiometer 33 is bridged across the hybrid coil 32 and has an input transformer 34 connected over the path P_{cb} to the amplifier A_b, a similar input transformer 35 being connected over the path P_{cf} to amplifier A_f. Similarly, a potentiometer 36 is bridged across the midpoints of the hybrid coil 30 and is associated with the input windings 37 and 38 leading through paths P_{bc} and P_{bf} to amplifiers A_c and A_f, respectively. Likewise, potentiometer 39 is bridged across the midpoints of hybrid coil 31, and input coils 40 and 41 are associated therewith in paths P_{fb} and P_{fc}, respectively, leading to the amplifiers A_b and A_c.

By means of this arrangement an independent transmission path is provided for transmission in each direction between any line and each of the other lines, the paths being balanced and independent of each other. By properly adjusting the gains of each amplifier the over-all transmission between any two stations of the group may be made the same as that between any other pair of stations. In order to take care of the echo conditions, one-half of a complete suppressor is required for each line connected at the common point, these units being conventionally indicated at S_b, S_c and S_f. The short circuiting contacts of each unit are connected to the bridged points of the corresponding hybrid coil so as to intercept echoes returning from the line. Consequently, if the transmitter of a particular line is operating, the voice currents coming into the center point pass through the suitable repeater paths to the other lines, and the echoes reflected from the distant terminals of the other lines return over said lines toward the center points but are suppressed by the short-circuiting contacts upon arriving at the center point.

The input terminals of the suppressor units must be connected so that operation will occur when transmission is from the center into the line but not when it is in the opposite direction. It is therefore not possible to connect the suppressor directly across the output of the amplifier as it would not only be operated by the amplified currents but might be also operated by currents incoming from the line and passing through the hybrid coil to the output circuit of the amplifier. The input of the suppressor unit is therefore connected between the first and second stage of the amplifier. The second stage tube thereby prevents transmission from the line back to the echo suppressor, but the echo suppressor will respond to currents transmitted through the amplifier path to the line.

By using two-stage amplifiers and connecting the suppressor in the stages as indicated in Fig. 2 the desired result may be accomplished of having the echo suppressor respond to transmission from the center out over the line but not operate for direct transmission from the distant station over the line to the center. While this arrangement involves the use of a two-stage amplifier such an amplifier would probably be required even if the echo suppressor units were not used because it is necessary to make the input transformers such as 37 and 38 low ratio transformers where the secondaries of several transformers must be connected in series, as is the case with the multiple-way repeater. If the ratios of these transformers were made high for the purpose of stepping up the potential which operates the amplifier, interference between the paths might result because of the capacity between the windings of the input transformers. This capacity might also impair the gain frequency characteristic of the repeater. If the transformers operate perfectly no interference can take place between paths. For example transmission through the transformer 34 and over the path P_{cb} to the amplifier A_b would not be diverted through the path P_{fb} and through the coils 40 and 41 back through the path P_{fc}, and amplifier A_c to the line L_c. This is for the reason that only potential changes appear on the secondary side of the transformer 34, and while these potential changes will operate the amplifier A_b, they cannot produce induced electromotive forces through the transformers 40 and 41 to operate the amplifier A_c. If, however, the transformers 40 and 41 were high ratio transformers so that the impedances would be large across these transformers, a capacity path between the windings of the transformer 34 would permit enough current to flow in the path P_{fb} as distinguished from mere potential variations to cause an appreciable disturbance. If currents were induced in this path through the transformer 34, obviously potentials might be induced through transformers 40 and 41 in the path P_{fc} to operate the amplifier A_c, thus causing interference.

With this arrangement also other two-wire suppressors may be used at suitable points at any or all of the two-wire lines where the echo suppressors at the central point are not sufficient to obtain the desired freedom from echoes and equality of transmission loss between local and distant stations. Likewise, if each two-wire line is supplied with one or more echo suppressors at intermediate points between its ends the echo suppressors at the central point may not be required. The arrangement shown accomplishes the result with a minimum of echo suppressing apparatus since only one-half of the complete echo suppressor equipment is required for each line.

It will be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from these illustrated without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. An interconnecting arrangement for several signaling stations, comprising an interconnecting station, transmission circuits from the several signaling stations to said interconnecting stations, means at said interconnecting station to enable any line to transmit to all others, and means to prevent currents transmitted over said interconnecting station out over the lines and then reflected back towards the interconnecting point from being transmitted through said interconnecting means.

2. An interconnecting arrangement for several signaling stations, comprising an interconnecting station, lines extending from each of said signaling stations to said interconnecting stations, means at said interconnecting station to enable any line to transmit to all of the other lines, and means to enable signals originating at the terminal of any line to be transmitted over said line to the interconnecting station for transmission to the other lines, said means being arranged to prevent currents transmitted from the interconnecting station over the lines and then reflected back, from being transmitted through said interconnecting station.

3. An interconnecting arrangement for several signaling stations, comprising an interconnecting station, lines extending from said signaling stations to said interconnecting station, means at said interconnecting station for interconnecting the lines so that any line may transmit to all of the others, said means including equipment for rendering the over-all transmission between any pair of stations substantially equal to the over-all transmission between any other pair of stations, and means to prevent currents transmitted through said interconnecting stations over the lines and then reflected back towards the interconnecting station, from passing through said interconecting station.

4. An interconnecting arrangement for several signaling stations, comprising an interconnecting station, lines extending from each of said signaling stations to said interconnecting station, means at said interconnecting station to interconnect the lines so that any line may transmit to all of the others, said means including amplifying arrangements whereby the over-all transmission equivalent between any pair of interconnecting stations may be made substantially equal to the over-all transmission equivalent of any other pair, and echo suppressing devices so associated with the lines that transmission originating at a signaling station may be transmitted over the corresponding line to the interconnecting station, said echo suppressor operating in response to transmission from the interconnecting station over the lines to prevent currents from being transmitted back from the terminal stations toward the interconnecting station.

5. An interconnecting arrangement for several signaling stations, comprising an interconnecting station, lines extending from each signaling station to the interconnecting station, a branched network at said interconnecting station for interconnecting the lines, the impedance of said net work looking into any branch being equal to the impedance looking into any other branch, amplifiers interposed between each line and the corresponding branch of the network to render the over-all transmission equivalent between any pair of stations substantially equal to the over-all transmis-

sion equivalent between any other pair of stations, and an echo suppressor associated with said amplifier, said echo suppressor being non-responsive to signaling currents originating at a signaling station and transmitted over the line through the amplifier to the branched network, but being responsive to signaling currents transmitted from the branched network toward the signaling station to prevent said transmission line from transmitting through the network.

In testimony whereof, we have signed our names to this specification this 22nd day of October, 1925.

ALVA B. CLARK.
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