Dec. 17, 1935. J. B. McKIM 2,024,592

TELEPHONE SYSTEM

Filed March 29, 1933 2 Sheets-Sheet 1

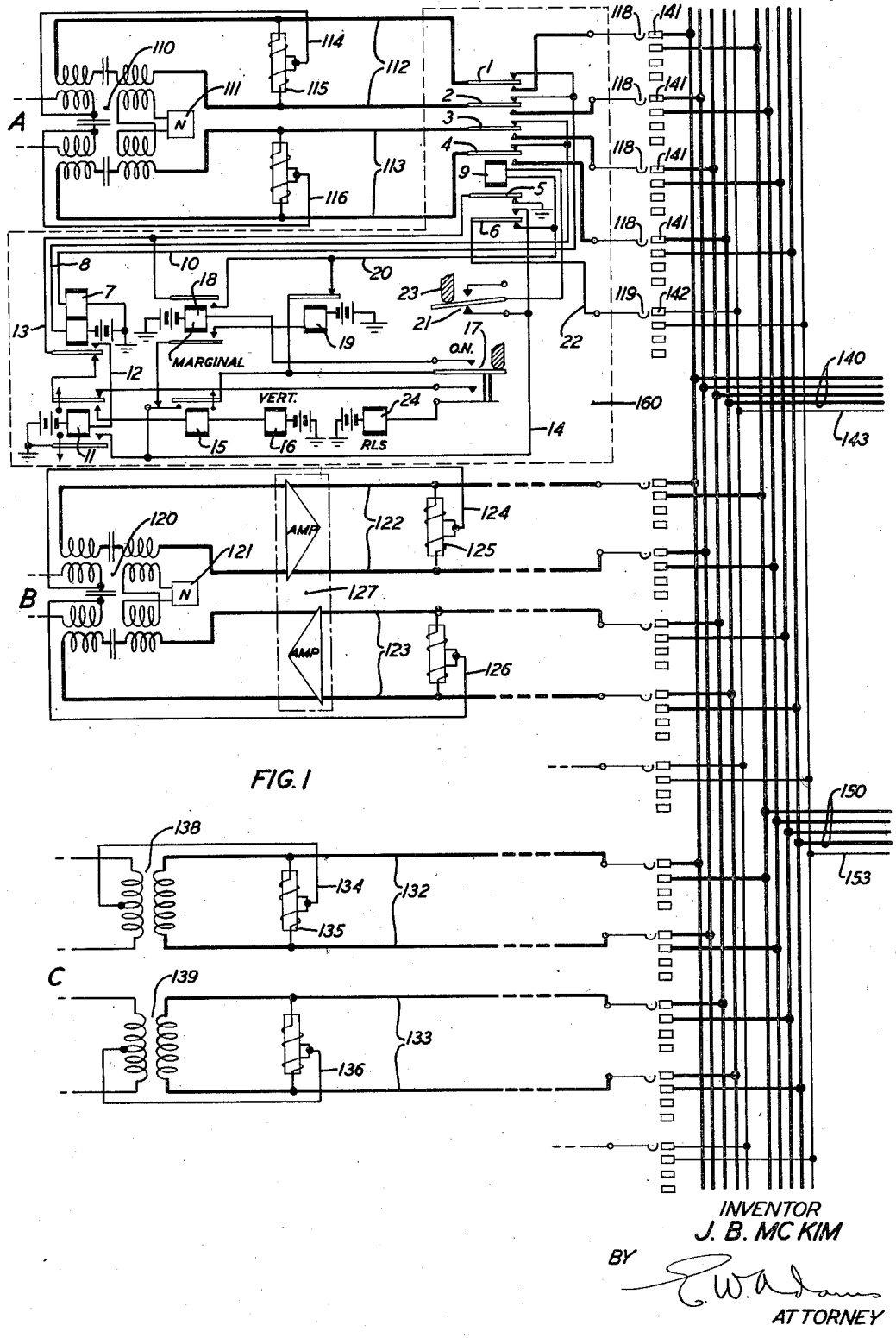


FIG. 1

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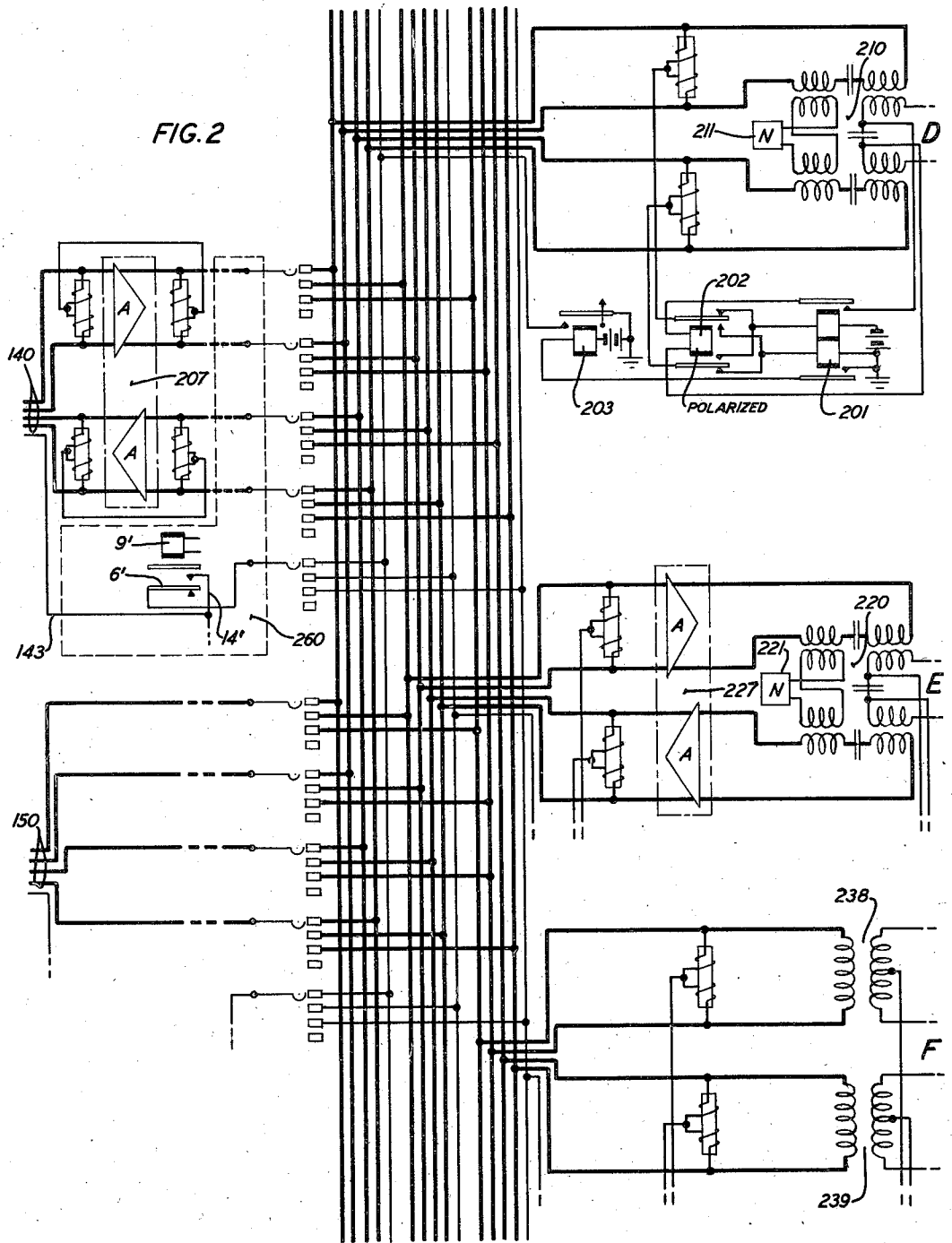
FIG. 2

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2,024,592

## TELEPHONE SYSTEM

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13 Claims. (Cl. 179—170)

This invention relates to transmission lines and more particularly to improvements in the arrangements for interconnecting such lines where repeaters are required on some of the connections.

An object of the invention is to interconnect such lines while maintaining a proper impedance balance on all connections.

When repeaters must be introduced into communication lines for transmission improvement, it is necessary to connect to a two-wire line a hybrid transformer and a balancing network, the transformer serving to connect the two-wire line to a four-wire section in which the repeaters are located. A second hybrid transformer and terminating network connect the other end of the four-wire section to the outgoing two-wire line.

A serious difficulty arises with such arrangements in balancing a two-wire line (or trunk) and the network associated with the hybrid coil. Without a proper impedance balance between the line and network the gain of the repeater must be kept at a comparatively low level or singing will occur.

Impedance balance is particularly difficult to achieve where pooled repeaters (that is, repeaters not permanently connected to any particular line) are used. In that case the network must have an impedance value equal to an average line and consequently will accurately match only a very few of the lines to which it will be connected.

Further difficulties would be encountered if automatic switches were used in making the connections involving the pooled repeaters. The contact resistances of these switches vary so much that consistent balances could not be obtained even with a perfectly matched line and network.

A feature of the present invention, therefore, whereby the above object is attained resides in permanently connecting four-wire sections to all two-wire circuits by means of hybrid transformers and balancing networks and in performing the necessary switching in said four-wire sections. With the switching done in the four-wire sections a hybrid transformer and network is individual to each line. Contact resistance acts merely to reduce transmission and does not increase unbalance or the tendency to sing.

The invention will be more fully understood from the following description together with accompanying drawings in which the invention is illustrated.

Figs. 1 and 2 of the drawings show, in schematic form, the switching arrangements in a telephone office arranged according to the present invention. They should be placed side by side with Fig. 1 to the left of Fig. 2. Fig. 1 shows telephone line or trunk circuits entering the telephone office from the west and automatic switching means for connecting these circuits to any of a plurality of interconnecting circuits. Fig. 2 shows the terminating ends of two of the interconnecting circuits with automatic switching means for connecting them to any of a plurality of outgoing line or trunk circuits to the east.

### *Circuit description*

In Fig. 1, A is a two-wire telephone line or trunk incoming from a distant office or station. It terminates in hybrid transformer 110 with which is associated balancing network 111. The hybrid transformer inductively connects the two-wire circuit to a four-wire circuit consisting of talking conductor pairs 112 and 113. Conductively connected to the tip conductor of the two-wire line is a signaling lead 114 which is simplexed to talking pair 112 by means of simplex coil 115. Signaling lead 116 connects the ring conductor of line A to talking pair 113 in like manner.

Associated with the four-wire section of line A are automatic switching arrangements for selecting any one of a plurality of four-wire interconnecting circuits, such as 140 and 150, and connecting the four-wire section of line A thereto. These arrangements consist of a step-by-step switching system 160 shown schematically within the dotted lines. The invention is not limited to step-by-step arrangements, however, but is equally applicable to other automatic switching systems (machine or panel type switching, for example).

Line B is a two-wire line or trunk similar to line A except that its transmission characteristics are such that it requires a telephone repeater on all connections. Four-wire two-way repeater 127 is permanently connected, therefore, in the four-wire section. The repeater is arranged to pass currents eastward in the talking pair 122 and westward in the talking pair 123. Signaling leads 124 and 126 are shunted around both the hybrid coil 120 and repeater 127 and are simplexed to the talking pairs. Line B has associated automatic switching arrangements similar to those associated with line A. These are arranged to connect the four-wire section of line B to any of the four-wire interconnecting circuits to which line A is arranged to be connected, such as 140 and 150.

Line C, in Fig. 1, is a four-wire line or trunk entering from another four-wire switching office. It is connected through transformers 138 and 139

to the terminating four-wire section comprising pairs 132 and 133. Signaling leads 134 and 136 are simplexed across the transformer. Line C likewise has automatic switching arrangements associated with it, similar to those associated with line A, to connect it to any of the previously mentioned interconnecting circuits. Line C is shown without a repeater connected to it, but it is understood that if it requires a repeater on all connections, one might be permanently associated with it in a manner similar to that shown for line B.

The interconnecting circuits are of two kinds. The first type, represented by 140 have four-wire two-way repeaters, associated with them and the second type, represented by 150 are direct four-wire circuits without repeaters.

Circuit 140 has repeater 207 (Fig. 2) associated with it. Automatic switching circuits 260, similar to circuits 160 associated with line A, are adapted to connect the outgoing end of circuit 140 to any of a plurality of outgoing line circuits, such as D, E and F.

Circuit 150, having no repeater, has automatic switching circuits (not shown) similar to 260 for connecting the outgoing end to any of the outgoing line circuits.

Outgoing line circuits D, E and F are similar in transmission features to incoming lines A, B and C, respectively, line D being a two-wire line terminating in hybrid coil 210, line E being a two-wire line terminating in hybrid coil 220 and having repeater 227 associated with its four-wire section, and line F being a four-wire line without repeater, it being understood that a repeater, if desired, may be permanently associated with this line as was the case with line C. The four-wire sections of these lines terminate in a plurality of terminal banks of automatic selector switches whereby any of the interconnecting circuits may be connected to them as previously described. These lines have associated with them certain signaling supervisory equipment such as the relays shown associated with line D.

The hybrid coils are so arranged that on connections including repeaters half the talking current energy incoming over a two-wire line is repeated into one pair of the four-wire section and half into the other pair. The network associated with the hybrid coils absorbs none of the incoming energy. The energy thus divided is amplified in the one pair, the amplified currents being repeated through the outgoing hybrid where half the energy is applied across the outgoing line and half is absorbed by the outgoing line balancing network. The energy in the other pair of the four-wire section is dispersed in the impedance of the output side of the amplifier in that pair. On connections where repeaters are not included, however, incoming talking currents are divided equally by the incoming hybrid into the two channels of the four-wire section and are recombined by the outgoing hybrid without loss of energy in either balancing network.

The above described arrangements will be more fully understood from the following description of their operation.

*Operation*

The originating end of two-wire line or trunk A will ordinarily be an operator's position at a switchboard in a nearby or distant office. In the present arrangement, such a position is assumed to be equipped with a dialing arrangement for sending pulses over line A in the usual manner. With this arrangement the distant operator may dial a combination of numbers which will connect line A through the four-wire switching office here shown to any of the lines or trunks outgoing from this office. If a repeater is to be needed on the connection and the operator knows that there is none in line A or in the called line, she will first dial a number individual to a group of interconnecting circuits provided with repeaters, such as circuit 140, and will then dial a number corresponding to the desired outgoing line or trunk, such as D, E or F. The switching arrangements will be set into operation by these dial pulses to connect line A to the desired outgoing line through a repeater such as 207. Should no repeater be required on the connection, or should one already be present in the calling or called line, the operator will dial a different first number individual to a group of interconnecting circuits without repeaters, such as circuit 150, after which she will dial a second number corresponding to the outgoing line desired. The arrangements may be much more complex than those shown in the drawings. For example, a plurality of interconnecting circuits might be arranged in series passing through several steps of automatic switching.

Assuming, in the present instance, that it is desired to connect line A to line D with a repeater in the connection, the distant operator connects her cord circuit to line A closing a circuit over line A through her dialing contacts to operate relay 7 as follows: From battery through the lower winding of relay 7, conductor 8, back contacts of armatures 3 and 4 of relay 9, in simplex on talking pair 113, lead 116, over line A, lead 114, simplex on pair 112, back contacts of armatures 1 and 2 of relay 9, conductor 10, upper winding of relay 7 to ground. Relay 7 in operating closes a circuit for operating relay 11 from battery, through relay 11, conductor 12, front contacts of relay 7, conductor 13, to ground on the back contact of armature 5 of relay 9. Relay 11 connects ground to conductor 14 at its lower contacts and prepares a path for the operation of relay 15 and vertical stepping magnet 16 at its upper front contacts.

When the calling dial is operated, causing a series of openings of the circuit over line A, relay 7 releases and reoperates in unison with the dial pulses but relay 11 remains operated since it has slow-to-release characteristics. Each time relay 7 releases, ground over conductor 13 is connected through its back contact and hence through upper front contacts of relay 11 to operate relay 15 and the vertical stepping magnet 16 causing the brushes 118 and 119 of a selector switch to be stepped in a vertical direction to terminal levels at which the interconnecting circuits containing repeaters are terminated. Relay 15, having slow-to-release characteristics, will remain operated until vertical stepping is completed. Vertical off-normal contacts 17 close as soon as the switch takes the first vertical step completing the circuit through contacts of relays 11 and 15 to operate relay 18. Relay 18 operates preparing a path for rotary hunting and locks up over a second circuit through contacts of relays 19, 18 and 9.

When relay 15 releases after vertical stepping is completed, the rotary magnet 19 operates in a circuit through contacts of relays 11, 15 and 18 and causes the switch to take one rotary step. As soon as rotary magnet 19 opens its contact relay 18 releases releasing magnet 19. Brush 119 is now in contact with one of the multiple bank terminals and if this terminal is grounded be-

cause of a busy condition, relay 18 will reoperate causing magnet 19 to step the brushes to the next terminal. This automatic stepping or hunting will continue until an idle or non-grounded terminal is found.

When an idle terminal is found, which in this case we will consider to be terminal 142 connected to the supervisory lead 143 of the circuit 140, high resistance relay 9 operates in series with relay 18 as soon as magnet 19 is released. The operating circuit extends from battery through relay 18, contacts 17, contacts of magnet 19, conductor 20, relay 9, contacts 21, contacts of relay 11 to ground. Relay 18 will not operate at this time due to the high resistance in series with it. Relay 9 disconnects the pairs 112 and 113 from relay 7 and connects them through brushes 118 and terminals 141 to circuit 140. Relay 9 also connects the supervisory lead 14 through sleeve lead 22, brush 119 and terminal 142 to supervisory conductor 143 of circuit 140. Conductor 143 is connected to supervisory lead 14' of switching circuit 260 which corresponds to lead 14 of circuit 160. Relays 7' and 11' (not shown) associated with circuit 260 operate responsive to the closure of the circuit over the talking leads by relay 9 and immediately connect ground to lead 14' and hence back over lead 143 to hold relay 9 operated before the first holding ground for relay 9 is removed by the release of relay 11.

If all the interconnecting circuits of the group had been busy, no idle terminal would have been found and the switch brushes would have passed off the bank of terminals and operated lever 23 opening contacts 21 thus preventing the operation of relay 9 and closing contacts (not shown) to connect busy tone back over the line to the calling operator. If the calling operator disconnects in response to the busy tone, or at any other time prior to the seizure of an idle interconnecting circuit, relays 7 and 11 will release energizing release magnet 24 which will operate to restore the switch to normal.

Assuming the line A has been connected to circuit 140, however, as just described, switching arrangements 260 function similarly to 160 to connect the circuit to outgoing line D responsive to the dialing of the second digit by the calling operator. When the connection is established and relay 9' (corresponding to relay 9), operates, it connects the talking pairs and lead 143 through to line D.

Relay 201 operates over the line circuit connecting polarized relay 202 across the outgoing two-wire section of line D and closing an energizing circuit for relay 203. Relay 203 connects ground to the supervisory lead to hold relays 9 and 9' operated.

The calling operator may now dial further digits which will be repeated by pulsing relay 201 out over line D. Relay 202 serves to relay supervisory signals back over the line to the calling operator. For example, when relay 201 first operates battery at the distant end of line D may be of such polarity that polarized relay 202 will not operate, but the polarity at the distant end may be reversed when dialing is finished to indicate a completion of the connection thus operating relay 202 which reverses the battery back over the line to the calling operator thereby affecting certain supervisory relays at her switchboard to indicate that the connection is complete.

On disconnection the calling operator withdraws, opening the calling line and causing relay 201 to release. This releases relay 203 removing ground from the supervisory lead thus causing release of relays 9 and 9' and allowing release magnets 24 and 24' to return the switches to normal.

By dialing the proper combinations of numbers, therefore, the calling operator may connect line A with any of the lines D, E or F through a pooled repeater or not, as required; similarly for lines B and C. All of the switching is done in the four-wire sections of the lines and the hybrid coils and networks are permanently connected to individual lines.

In a four-wire switching arrangement all the circuits may enter an office as two-wire lines and trunks, such as lines A and B. However, in an area where there are several four-wire switching offices, many four-wire lines or trunks such as C and F may interconnect the offices in order that there will be as few hybrid connections as possible in a through circuit.

While the invention has been shown and described as applied to certain specific arrangements, applicant does not wish to be limited by such disclosure, but desires to cover broadly all arrangements which come within the spirit and scope of the appended claims.

What is claimed is:

1. In a telephone system, a central office, a plurality of two-wire channels terminating thereat in individual four-wire sections, transforming means coupling each two-wire channel and its associated four-wire section, certain of said two-wire channels and their four-wire terminations being incoming and certain others being outgoing, and automatic selector switching means for interconnecting the free ends of any incoming four-wire sections to the free ends of any outgoing four-wire section.

2. In a telephone exchange system, a central office, a plurality of two-wire channels terminating thereat in individual four-wire sections, transforming means coupling each two-wire channel and its associated four-wire section, certain of said two-wire channels and their four-wire terminations being incoming and certain others being outgoing, a balancing network associated with each said transforming means, and automatic selector switching means for interconnecting the free ends of any incoming four-wire sections to the free ends of any outgoing four-wire sections.

3. In a telephone system, a central office, a plurality of two-wire channels terminating thereat in individual four-wire sections, transforming means coupling each two-wire channel and its associated four-wire section, certain of said two-wire channels and their four-wire terminations being incoming and certain others being outgoing, a balancing network associated with each said transforming means for balancing the impedance of the associated two-wire channel, and automatic selector switches for interconnecting the free ends of any incoming four-wire sections to the free ends of any outgoing four-wire sections.

4. In a telephone system, a central office, a plurality of two-wire incoming and outgoing trunk circuits terminating thereat, a four-wire section terminating each said trunk comprising two talking channels, a hybrid transformer connecting each said four-wire section to its associated trunk, a balancing network associated with each said transformer simulating the impedance

of its respective trunk, and automatic selector switches for connecting the individual conductors of any incoming four-wire section with the corresponding conductors of the four-wire section of any outgoing trunk.

5. In a telephone system, a plurality of incoming and outgoing two-wire lines, a four-wire section in each said line comprising two talking channels, a hybrid transformer connecting each said four-wire section to its associated line, a balancing network associated with each said transformer simulating the impedance of its respective two-wire line, four-wire telephone repeaters, and automatic selector switches controlled over a calling one of said two-wire lines for connecting the individual conductors of the four-wire section of the calling line with the corresponding conductors of the four-wire section of any outgoing line either directly or through one of said repeaters.

6. In a telephone system, a central office, a plurality of incoming and outgoing two-wire lines, terminating thereat in individual four-wire sections, a hybrid transformer between each said two-wire line and its associated four-wire section and permanently connected to said two-wire line, a balancing network permanently associated with each said transformer and simulating the impedance of its respective two-wire line, and automatic selector switching means in said four-wire sections controlled over a calling two-wire line for interconnecting the calling line with any outgoing line.

7. In a telephone system, an incoming two-wire line, a four-wire line, a transformer permanently interconnecting said lines, a balancing network for said two-wire line permanently associated with said transformer, other incoming and outgoing two-wire and four-wire lines interconnected in like manner, and selector switches intermediate said incoming and outgoing four-wire lines and controlled over the two-wire lines for interconnecting the individual conductors of the incoming and outgoing four-wire lines for conversation.

8. In a telephone system, an exchange, a two-wire line terminating thereat in a four-wire line, a transformer permanently interconnecting said lines, a balancing network for said two-wire line permanently associated with said transformer, a second two-wire line terminated at the exchange in a second four-wire line and connected by a transformer including an associated balancing network, a third two and a third four-wire line also connected by a transformer and its associated network at the exchange, and automatic selector switching means intermediate said four-wire lines adapted to connect individual conductors of one four-wire line with the respective conductors of the second or third four-wire line.

9. In a telephone system, an exchange, a two-wire line terminating thereat in a four-wire line, transformer means permanently joining said two and four-wire lines, a network permanently associated with said transformer and simulating an impedance balance of said two-wire line, a four-wire repeater, second and third two-wire lines and second and third four-wire lines interconnected at the exchange by second and third transformers respectively including impedance balancing means for said respective second and third two-wire line, and automatic selector switching means for interconnecting any two of said four-wire lines through said repeater.

10. In a telephone system, a two-wire line, a four-wire line, transformer means permanently joining said two and four-wire lines, a network permanently associated with said transformer and simulating an impedance balance of said two-wire line, a four-wire repeater, second and third two-wire lines and second and third four-wire lines also interconnected by transformers, impedance balancing means for said second and third two-wire lines associated with the respective transformers, and selector switches adapted to be controlled over any two-wire lines, to interconnect its associated four-wire line with either of the other two four-wire lines through said repeater.

11. In a telephone system, a two-wire line, a four-wire line, transformer means permanently joining said two and four-wire lines, a network permanently associated with said transformer and simulating an impedance balance of said two-wire line, a four-wire repeater, a plurality of other two-wire lines connected to four-wire lines by other transformers including impedance balancing means for their respective two-wire lines and an automatic selector switch mechanism adapted to connect together the conductors of said four-wire lines either directly or through said repeater.

12. In a telephone system, a two-wire line, a four-wire line, a four-wire repeater connected in said four-wire line, a transformer interconnecting said two and four-wire lines, a balancing network for said two-wire line permanently associated with said transformer, a second two-wire line, a second four-wire line connected to said two-wire line by a second transformer including a second balancing network for balancing the impedance of said second two-wire line, a second four-wire repeater connected in said second four-wire line, a third two-wire line and a third four-wire line interconnected by a third transformer including a third balancing network for said third two-wire line and automatic switching means adapted to interconnect the individual conductors of said first four-wire line to the respective conductors of said second or third four-wire lines.

13. In a telephone system, a central office, a plurality of lines centered therein for interconnection, a hybrid transformer terminating the office end of each of said lines, said transformer having independent transmitting and receiving channels extending therefrom, a compensating network associated with each transformer, said networks having impedance characteristics simulating the associated line, a four-wire repeater having input and output channels for each transmission direction and selective switching means adapted to connect the transmitting and receiving channels of one hybrid coil to respective input and output circuits of said repeater and to connect the other output and input circuits of said repeater to the respective receiving and transmitting channels of the hybrid transformer terminating another one of said lines.

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