Jan. 18, 1927. 1,614,545

R. W. DEARDORFF

CARRIER TELEGRAPH CIRCUITS

Filed July 31, 1923 2 Sheets-Sheet 1

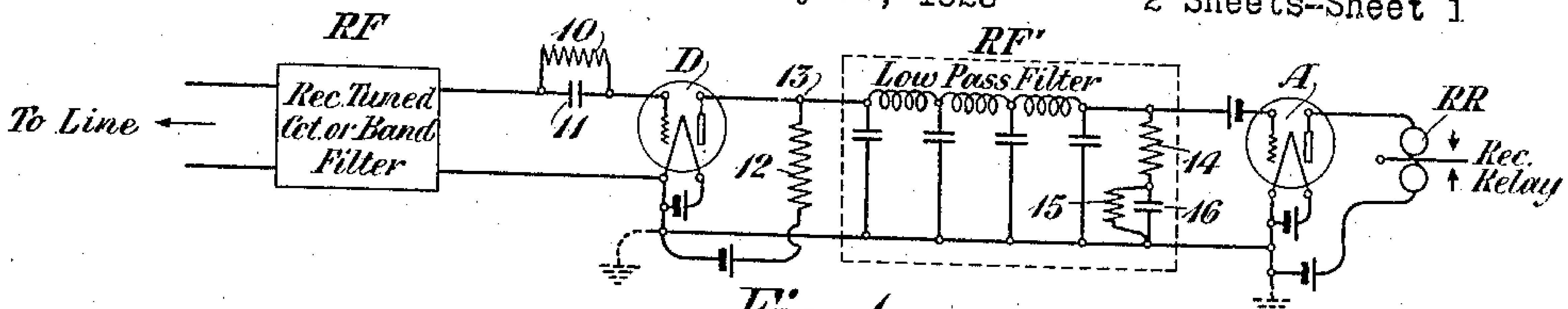

Fig. 1

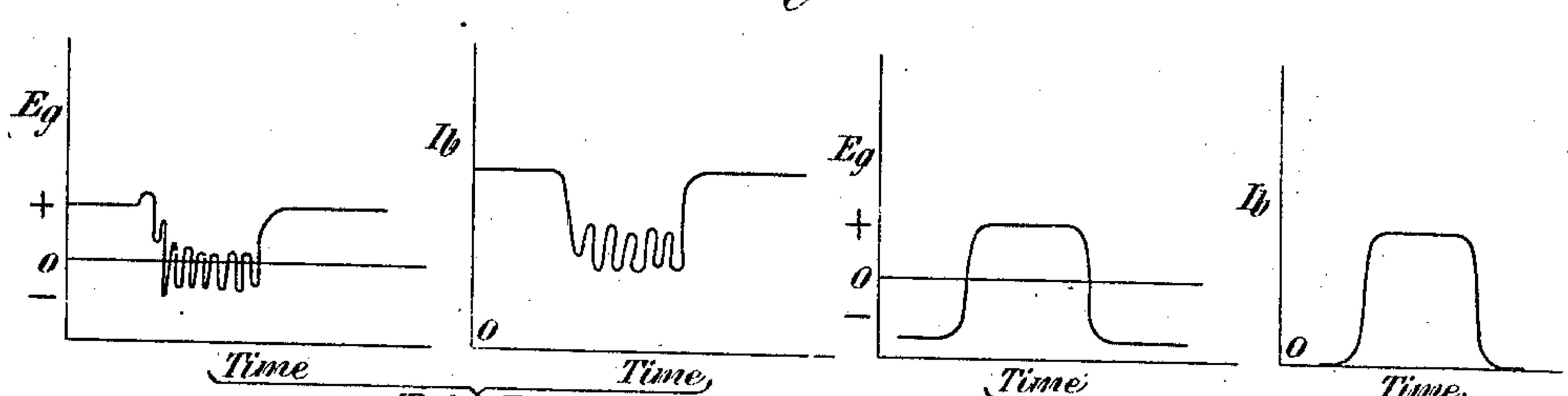

Fig. 2 Fig. 3 Fig. 4 Fig. 5

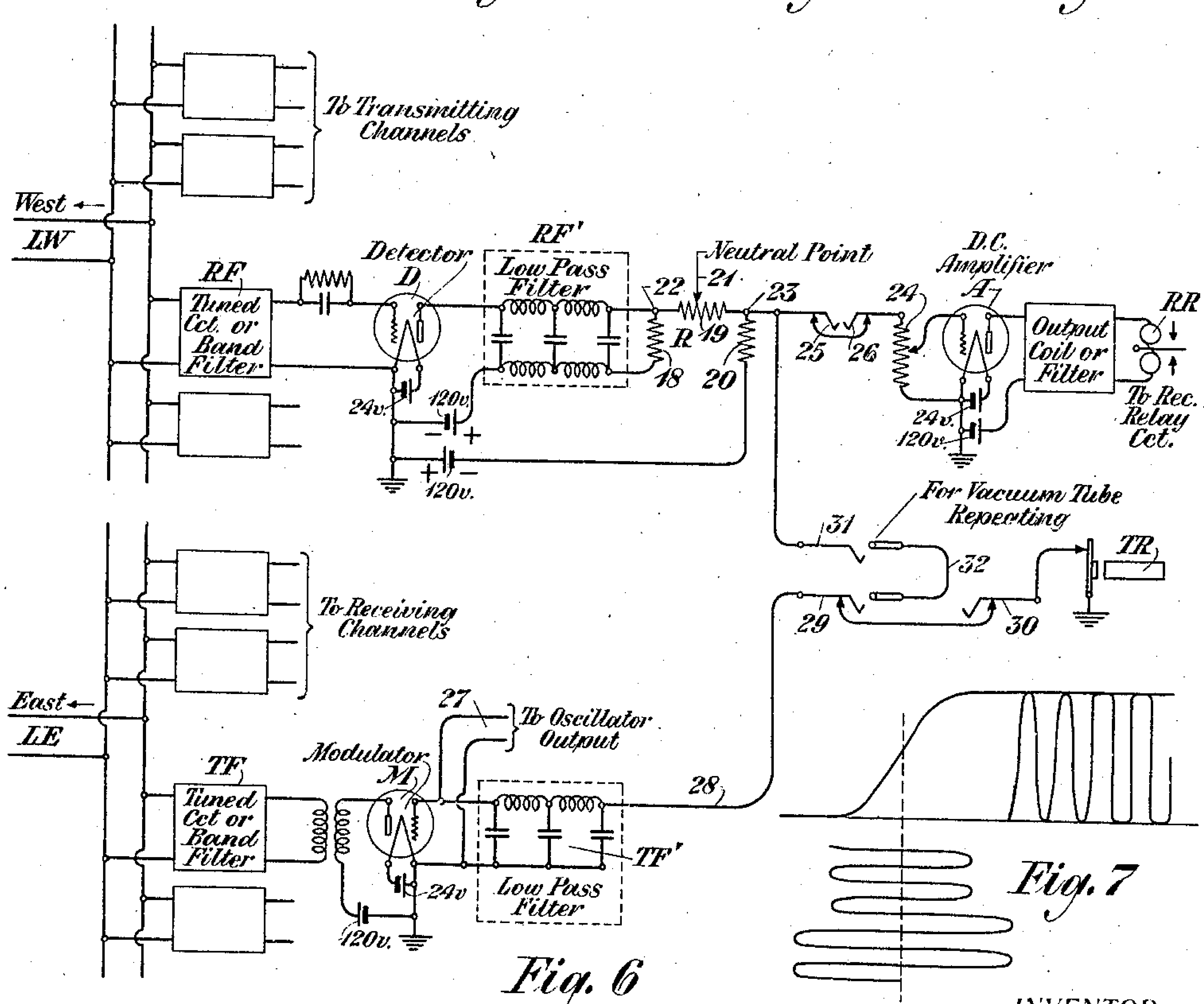

Fig. 6

Fig. 7

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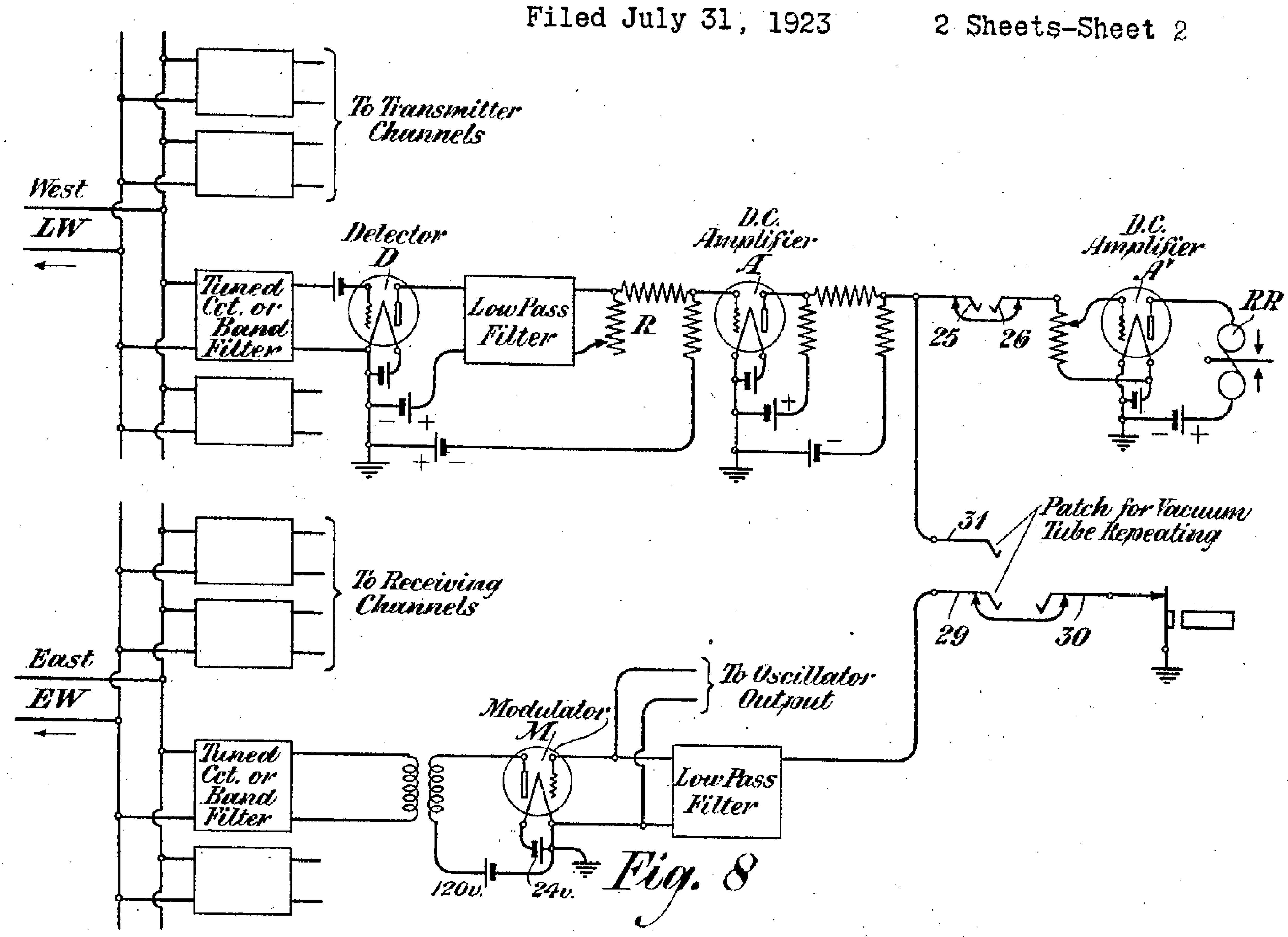

Fig. 8

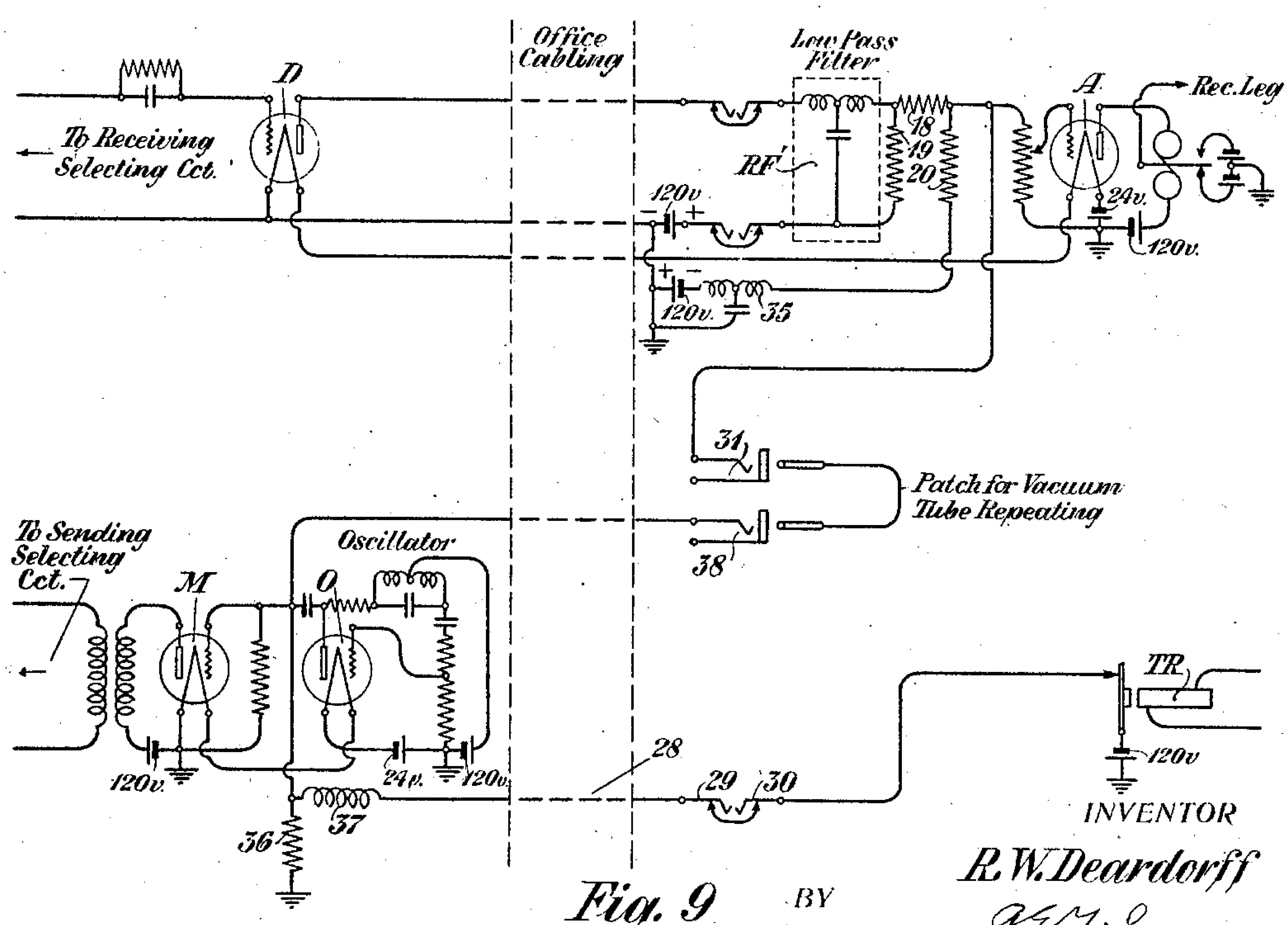

Fig. 9

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UNITED STATES PATENT OFFICE.

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CARRIER TELEGRAPH CIRCUITS.

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This invention relates to multiplex signaling, and more particularly to multiplex systems employing carrier currents for the transmission of telegraph signals. One of the objects of the invention is to provide a multiplex carrier telegraph circuit arrangement in which the circuit apparatus may be divided at such a point in the circuit that the low frequency apparatus can be separated from the high frequency apparatus, thus permitting of improved methods of mounting the equipment units upon racks and also enabling the operation of east and west repeating circuits on adjacent sets. Another object of the invention is to provide a multiplex carrier telegraph circuit which will permit of vacuum tube repeating between carrier line sections at low frequency and without the interposition of relays between the receiving channel of the incoming line and the sending channel of the outgoing line. Another object of the invention is to provide a circuit arrangement of the class above described which will more effectively exclude beat frequencies from the circuit of the receiving relay of the receiving channel. Other and further objects of the invention will more fully appear hereinafter.

In multiplex carrier telegraph systems of the prior art, it has been customary and in fact necessary to arrange upon a common panel all of the apparatus of a number of channels superimposed upon a given line. The location of the apparatus upon the panel was determined by the amount of space available, and this sometimes resulted in a sacrifice of convenience. In accordance with the present invention, the circuit arrangements are such that the apparatus may be made up in the form of units, so that the high frequency apparatus of a given receiving channel may form one unit, for example, the low frequency apparatus of the same channel forming another unit, and in a similar manner the high and low frequency parts of the transmitting channels may form separate units. The different units may then be symmetrically mounted upon racks, and where (as will usually be the case) it is necessary to locate the low frequency apparatus at a different point of the office from the high frequency apparatus, the connections between the units may be made through the office cabling. With the apparatus segregated and mounted in this manner, it becomes a very simple matter to patch any given unit of low frequency apparatus to any desired unit of high frequency apparatus so that the arrangement becomes much more flexible.

Another difficulty encountered in connection with prior art systems has to do with the interconnection of incoming channels of one line with outgoing channels of another line for through repeating. It has heretofore been impossible to patch the carrier channels of opposite directions to adjacent panels because of the excessive losses which are introduced into the high frequency circuit by the office cabling. It is apparent, however, that if the high frequency signals are converted to low frequency signals before the patch is made, it will be possible to introduce a considerable amount of office cabling without materially affecting the quality of the telegraph signals.

In order to attain this result and the other results discussed, the arrangement of the vacuum tubes in the receiving channel is changed. Heretofore the first tube or tubes in the circuit have been used as high frequency amplifiers and the last tube as a rectifier or detector from the output of which the receiving relay is operated. In accordance with the present invention, the first tube will serve as a detector and the subsequent tubes as direct current or signal amplifiers.

This rearrangement of the apparatus renders it possible to keep such equipment as the amplifiers and receiving relays away from the racks upon which the high frequency units are mounted, in order that adjustments which are necessary to compensate for weather variations may be made by the attendant at the receiver. This part of the equipment would normally be mounted upon tables or racks convenient to the operator. The operator can then readily adjust the relay or the gain of the amplifier as weather variations may require. The transmitting oscillator and amplifier of the transmitting channels can be made to deliver current to the line of sufficient constancy, so that little or no attention will have to be given to this apparatus, and, as a consequence, it may be mounted upon the same racks as the high frequency equipment of the receiving channels.

The rearrangement of the circuit above referred to, together with the distribution of the apparatus in the office racks, renders it possible to patch from the output of the detector to the modulator of the transmitting channel, so that signals may be repeated in the low frequency state directly from the detector of one receiving channel to the modulator of any given transmitting channel without the use of intervening relays. The patching may be done at a point near the racks or tables upon which the low frequency equipment is mounted by carrying leads from the output of the detectors and from the input of the modulators to these points through the office cabling. As the transmission through the cabling will thus take place at the low frequency state, no difficulty will be involved in patching from one circuit to another as the exigencies of a particular situation may warrant.

By rearranging the apparatus of the receiving channel so that amplification takes place after detection, the filter, which will be inserted between the detector and amplifier to suppress frequencies higher than the low frequency signals which are to be received, may readily be designed to cut off any interfering beat frequencies higher than the normal telegraph frequency.

The invention may now be more fully understood from the following detailed description when read in connection with the accompanying drawing in which Figure 1 is a simplified diagram showing the arrangement of the apparatus in a receiving channel in accordance with the present invention. Figs. 2, 3, 4 and 5 are curves illustrating the operation of the different vacuum tube elements of the receiving channel. Fig. 6 is a simplified diagram showing the circuit arrangements of a typical transmitting channel and a typical receiving channel, together with patching arrangements for patching between different high frequency and low frequency units and for patching between transmitting and receiving channels for through repeating. Fig. 7 is a curve illustrating the operation of the modulator in accordance with the present invention. Fig. 8 is a diagram similar to that of Fig. 6, showing a modified arrangement, and Fig. 9 is a circuit diagram showing how the units of the channels may be interconnected through the office cabling.

As has been previously stated, the principle involved in the present invention is that of detecting in the first tube of the receiving circuit and the use of direct current amplification in the succeeding stage or stages. This is illustrated in simplified form in Fig. 1 in which RF is a tuned circuit or band filter interposed between the receiving channel and the high frequency transmission line to select to the channel the particular band of modulated carrier frequencies which carry the signal for that particular channel. A detector D, such as a vacuum tube detector, for example, is connected in circuit on the channel side of the filter. A low frequency amplifier A, which is preferably of the vacuum tube type, is included in circuit beyond the detector for amplifying the detected low frequency signals. The receiving relay RR is connected to the output circuit of the amplifier A, and a low-pass filter RF′ is included between the detector D and the amplifier A.

The input circuit of the detector D is provided with a grid leak 10 and a condenser 11, these elements being of a well known type. This arrangement of the input circuit has certain advantages over the so-called C battery type of detector, as it is found that in telegraph work a slightly larger amount of gain can be realized in the detector tube. An additional advantage of this circuit resides in the fact that the phase of the received signals will come out right with a smaller number of tubes when the grid leak-condenser arrangement is used than when the C battery type of detector is used.

This will be clear from the curves of Figs. 2, 3, 4 and 5. Fig. 2 is a curve showing the changes of the grid potential with time. Normally the potential of the grid will have a certain positive value as indicated, this positive value being due to the connection existing between the grid and the battery for heating the filament. As carrier oscillations are impressed upon the grid, however, the succeeding oscillatons are trapped upon the grid by means of the condenser (due to the fact that current can only flow one way through the tube) until a state is reached dependent upon the rate of leak through the resistance 10 such that no further increase in the negative charge trapped upon the grid can take place. The potential will then vary in accordance with the high frequency waves, but the average potential will remain fairly constant. At the end of the train of waves the potential will again assume its normal value, the negative charge on the grid having leaked away through the resistance 10.

Fig. 3 indicates the change in the output current of the detector tube D. The current will have the normal positive value determined by the normal positive potential of the grid, but as the potential of the grid decreases or changes from positive over toward the negative as successive charges are trapped upon the grid in response to the received waves, the output current decreases. At the end of a train of waves the output current again assumes its normal value. It will thus be seen that a train of waves, corresponding to a telegraph dot or dash, produces during the interval that the train persists an average reduction in the potential applied to the detector tube and a corresponding average reduction in the output current.

At the amplifier A, however, the phase of the low frequency wave is reversed. Normally a potential is applied to the grid of the amplifier which has a negative value (determined by the C battery and by the plate potential from the detector tube D) such that no current flows in the output circuit as will be clear from a comparison of Figs. 4 and 5. When, however, a decrease occurs in the current flowing in the plate circuit, that is, in the current flowing from the B battery, through the output resistance 12 and across the gap between the plate and the filament, the internal impedance of the tube D is increased. This will be apparent from the fundamental relation between voltage current and impedance, for, if the voltage remains constant and the current decreases, the impedance must increase. This increases the IR drop through the tube, so that the potential at the point 13 becomes less negative than is normally the case, or, in other words, its potential is raised. This produces an increase in the positive component of the potential applied to the grid of amplifier tube A, so that the potential of the grid of the tube A shifts from a given negative value toward the positive as indicated by the curve of Fig. 4. As the grid becomes less negative, the plate current increases as indicated in Fig. 5. The current curve of Fig. 5 is properly phased to operate the receiver if a current pulse or an increase in current corresponds to a train of carrier oscillations impressed upon the line.

The filter RF′ is composed of relatively few sections. As the input circuit of the amplifier A has practically infinite impedance due to the fact that no current can flow between the grid and the filament when the grid is made sufficiently negative, the impedance, looking into the filter from the detector, will not be equivalent to that of an infinitely long line. It is therefore desirable to terminate the filter on the side adjacent the amplifier in a simple network consisting of resistances 14 and 15 and capacity 16 designed and proportioned in a well known manner to simulate the impedance of an infinitely long line over the range of frequencies passed by the filter. The provision of this network enables the filter to give a close approximation of the action of a theoretic filter having an infinite number of sections. The filter RF′, which is provided primarily in order to keep the high frequencies which appear in the output circuit of the detector from being transmitted to the input circuit of the amplifier, also may be made to serve an additional purpose, viz., that of suppressing beat note frequencies of the order of 200 or 300 cycles which sometimes result from the interaction in the detector of interfering frequencies.

In applying a circuit of the type illustrated in Fig. 1 to plant operation, it is desirable to utilize the 120 volt Morse batteries as well as the 24 volt battery commonly used in plants for the purpose of supplying the plate and filament currents and also the C or grid potential. These batteries are normally grounded as used in the plant, and while this does not interfere with their use for filament and plate currents, as will be apparent from the dotted ground connections indicated in Fig. 1, it is impossible to use a grounded battery for supplying the grid potential of the amplifier A. It will be apparent from the diagram that if ground be applied on either side of the C battery of the amplifier A, it will result in short-circuiting the grid, so that the signal potentials will not be applied to the grid and hence will not be amplified. This would necessitate the provision of a separate dry cell battery for each amplifier.

Fig. 6 illustrates a circuit arrangement in which this difficulty is overcome. Fig. 6 also illustrates the manner in which the high frequency and low frequency apparatus may be segregated into units and the various patching connections effected. A transmitting channel and receiving channel are illustrated in some detail in Fig. 6, and their manner of association with carrier frequency lines is also indicated. The transmitting and receiving channel, shown in detail, are not, however, arranged to be operated together in connection with one carrier line to form a two-way communication channel, but are each shown as connected to different line sections incoming to the station from different directions, so that the two channels may be, if desired, connected together to repeat from the one line section to the other. Accordingly, the line LW, going west, is shown terminated in bus bars to which are connected a plurality of transmitting and receiving channels separated from each other by filters such as RF. The details of the transmitting channels associated with the line LW are not shown, it being understood that these channels will be similar to the channels illustrated in connection with the line LE to be described hereinafter. The apparatus associated with one receiving channel only is shown in detail and comprises the receiving filter RF, a detector D, a low-pass filter RF′ and A. D. C. amplifier A, having the receiving relay RR in its output circuit. If desired, the output circuit of the amplifier may include a coil or filter for preventing the transmission of high frequencies to the receiving relay RR.

The detector D is of the grid leak type illustrated in Fig. 1. The low-pass filter

RF′ is also similar to that of Fig. 1, but in this instance the network 14, 15 and 16 is omitted, and the filter is terminated by a resistance 18 which is made substantially equal to the impedance of an infinitely long line at the principal frequency to be transmitted through the filter.

The filaments of the detector D and amplifier A are supplied with current from the grounded 24 volt battery. The plate currents are supplied from the positive side of the grounded 120 volt Morse battery. In order to provide the necessary C potential for the grid of the amplifier A from the negative side of the 120 volt grounded Morse battery, the positive and negative Morse batteries are connected to a resistance bridge comprising resistances 18, 19 and 20. It will be apparent that there will be a continuous change in potential through the several resistances beginning with 120 volts positive at the lower terminal of resistance 18 passing through a neutral point of zero potential at 21 of resistance 19 and ending in a point whose potential is 120 volts negative at the lower terminal of resistance 20. The plate of the detector D is connected to a point 22 so chosen that the resistance 18 will have the desired value for terminating the filter RF′ and so that the point will have the desired positive potential for the plate. A point 23 is also chosen having the desired negative potential for the grid of the amplifier A. A suitable potentiometer may, if desired, be included in the input circuit of the amplifier A for the purpose of making minor adjustments in the C potential.

Jacks 25 and 26 are included in circuit between the detector D and the amplifier A, as indicated. These jacks may be positioned at a testboard, or at some point adjacent to the receiving operator, thereby enabling the attendant to switch the low frequeny apparatus, which is preferably mounted on a table or rack at or near the operating room, into connection with any desired detector and associated apparatus of any line. This permits of great flexibility of operation. The detector and associated high frequency equipment may be mounted as a unit upon a rack at some distant point in the office.

LE designates another high frequency or carrier line extending east from the station illustrated, said line terminating in bus bars to which are connected a number of transmitting and receiving channels. The apparatus of the receiving channels is not illustrated but will be understood to be similar to that described in connection with the line LW. The apparatus of only one transmitting channel is illustrated and includes a tuned circuit or band filter TF for separating the channel from the other channels associated with the same line. A modulator is associated with the filter, the modulator comprising a vacuum tube arrangement M whose input circuit may be normally supplied with a carrier frequency from a circuit 27 leading to some suitable carrier source such as, for example, a vacuum tube oscillator. The frequency supplied to the modulator from the oscillator may be interrupted in accordance with signals by a connection 28 leading from the grid through a low-pass filter TF′ to a transmitting apparatus TR. The filter TF′ serves the purpose of curbing or rounding off the telegraph or Morse impulses.

Jacks 29 and 30 may be included in the circuit 28 at a testboard or other point near the operating table whereby the transmitter may be patched to any desired modulator. This arrangement enables the low frequency transmitting apparatus to be separated from the high frequency apparatus, such as the modulator and its associated equipment. The high frequency equipment will preferably be made up as a unit and mounted on racks along with the high frequency units of the various receiving channels. By means of the jack 29 in the transmitting circuit and a jack 31 associated with the output of the detector D. a connection may be established through the patching cord 32, so that the detector D repeats directly into the modulator M. In this manner any receiving channel may be patched to any transmitting channel for through repeating, and it will be observed that the signals are repeated in their low frequency state without the use of any relays. This is advantageous where the repeating connection passes through a considerable amount of office cabling, as the attenuation of the cable does not seriously distort the low frequency signals, whereas, if the transmission took place at carrier frequencies, a much greater amount of distortion would occur.

With this method of repeating some provision must be made to keep the amplitude of the signals fairly uniform under different attenuation conditions of the circuit due to weather variations, as otherwise the effects of the weather variations would have a cumulative action in a system having any considerable number of repeater points. For example, if the condition should be such that the incoming detected signal obtained from the detector of one repeater is greater than the normal signal, it will be impressed upon the modulator of the corresponding repeater to produce a greater amplitude of variation at the transmitting point than will ordinarily be sent out, Accordingly, at the next repeater point the signal will be still greater, and it may finally become so great as to overload the tubes.

This difficulty may readily be remedied by operating the modulating tubes at saturation. The action of these modulators may be understood from Fig. 7, which shows the characteristic grid potential-plate current curve of the modulator. It will be seen from this diagram that an increase in the amplitude of the applied carrier frequency will not produce an increase in the amplitude of the output current of the modulator, as the saturation part of the curve tends to maintain the amplitude constant, and the only effect of the increase in amplitude of the input potential will be to produce a flattening of the tops of the waves in the output circuit.

Where a sufficient amount of amplification is not obtained in the receiving channel by the use of a single amplifying tube, it may be desirable to use a detector of the C battery type, as this type of detector will have the effect of bringing out the received wave in the output of the additional amplifying tube in the right phase. A circuit for this purpose is illustrated in Fig. 8. In this figure, A represents the detecting tube and A and A′ two low frequency amplifying tubes. The dectecting tube is supplied with a C battery potential in any well known manner, while the plate potential of the detector and the C potential of the amplifier A are supplied by a resistance bridge in the manner described in connection with Fig. 6. The plate potential of the amplifier A and grid potential of the amplifier A′ are likewise provided through a similar resistance bridge arrangement.

The effect of a train of carrier oscillations corresponding to a signal when impressed upon the grid of the detertor D is to produce an increase in the current flowing in the plate circuit of the detector, as the normal C potential of the grid will be adjusted so that the detector is operating near the lower knee of its characteristic curve. When operated at this point, the effect of the positive half of each high frequency wave is to produce an increase in the normal plate current, while the effect of each negative half wave is to produce a much smaller decrease in the normal plate current. The train of waves therefore produces on the average an increase in the plate current. Accordingly, if we contrast this action with the action indicated by the curves of Figs. 2, 3, 4 and 5, it will be seen that the increase in the current in the detector circuit produces a decrease in the potential applied to the first amplifier A, so that a corresponding decrease in current will appear in the output circuit of the amplifier. The decrease in the current produces an increase in the potential applied to the grid of the two-stage amplifier, which, in turn, produces an increase in the current in the output circuit. This produces a wave in the output circuit of the amplifier A′ which corresponds to the wave for the tube A of Fig. 1, as illustrated in Fig. 5. Consequently the combination is such that the wave in the output circuit of the amplifier is in the right phase relation.

The transmitting apparatus will be similar to that illustrated in Fig. 6 and need not be described. Jacks 25 and 26 are shown as being arranged between the first-stage tube and the second-stage tube of the amplifier, so that the first-stage amplifier may be mounted with the high frequency unit. This is desirable for the reason that no potentiometer is provided in connection with the amplifier A for adjusting the gain. The second-stage amplifier, which is provided with a potentiometer, will then be mounted with the relay equipment at a point near the operator's station. The jack 31 is connected to the output circuit of the amplifier A in Fig. 8 rather than to the output circuit of the detector D as in the case of Fig. 6, for the reason that, when a patching connection is to be established through jacks 31 and 29 to a transmitting channel for through repeating, the low frequency wave will have the right phase for this purpose as it appears in the output circuit of the first amplifier. This is due to the reversal of phase introduced by the C battery type of detector. This circuit arrangement has the same advantages from the standpoint of mounting the apparatus in units and from the standpoint of office cabling as that of Fig. 6.

A circuit is illustrated in Fig. 9 somewhat similar to that of Fig. 6, this circuit being arranged to show how the cabling between the high frequency apparatus mounted on one set of racks and the low frequency units mounted upon other racks may be accomplished. The circuit arrangement of Fig. 9 also shows certain refinements for overcoming a few practical difficulties which are encountered in an arrangement of this character. In Fig. 9 the detector D is as illustrated in Fig. 6, but the circuit differs from that of Fig. 6 in that the low-pass filter RF′ is removed from the part of the circuit immediately upon the output side of the detector D and is inserted in the circuit adjacent the input of the amplifier A, thus making the low-pass filter a part of the low frequency equipment. This cabling then intervenes between the low-pass filter and the output side of the detector. This prevents the grid of the direct current amplifier A from picking up interfering potentials which are usually present in office wiring. The resistance bridge 18, 19 and 20, through which the plate potential of the detector D and the grid potential of the amplifier A are provided, is also made a part of the low frequency equipment. A filtering arrangement 35 is provided in the negative Morse battery tap which supplies the grid potential for the purpose of reducing fluctuations and noise which are usually present in such batteries. The patching jacks for patching the low frequency equipment to any detector unit are arranged between the filter and the detector at a testboard near the receiving operator, so that the patching may be readily accomplished.

The transmitting equipment is substantially the same as that illustrated in Figs. 6 and 8 except that the connection 28 from the grid of the modulator to the transmitter TR includes a 120 volt C battery at the transmitter. This C battery enables the modulation to be accomplished by varying the grid potential rather than by short-circuiting the oscillator by grounding the grid as in the previous figures. By using C battery modulation, the transmitting relay TR may be mounted at the operating table instead of at some point near the modulator as would be necessary if the ground method of modulation were employed. This is for the reason that, if the ground were applied at some distant point involving a considerable length of cable in the wire 28, the effect of applying the ground would not be to short-circuit the modulator but only to partially shunt it, so that as a consequence the modulation would be less effective. The C battery method, however, enable the adjustment of the potential applied when the C battery is connected to the grid to such a value that no current flows in the output circuit, thereby, in effect, completely interrupting the transmission of carrier oscillations. In order to round off or curve the telegraph impulses, a filter consisting of a resistance 36 and inductance 37 is provided in the circuit 28. The inductance rounds off the current wave transmitted over the wire 28, and the resistance 36 is necessary in order to draw current through the inductance, the inductance 37 having no effect upon mere potential changes. The jacks 29 and 30 serve for patching between different transmitters and modulators as in the other figures, while jacks 31 and 38 may be used to patch between the output of the detector D and the input of the modulator M for through repeating. The various patching jacks are all preferably arranged at the Morse board, or other convenient point, so that great flexibility in patching up connections is possible.

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

What is claimed is:

1. In a carrier telegraph system, a transmission line terminating at a central station, a receiving channel associated with said transmission line, said channel including a detector for detecting low frequency telegraph signals from the carrier currents received, said detector being located at one point in said station, cabling extending from said point to a distant point in said station, an amplifier for said channel functioning to amplify detected signals, said amplifier being located at said distant point at said station, and connections between said detector and said amplifier extending through said office cabling.

2. In a carrier telegraph system, a plurality of carrier receiving channels each having high frequency apparatus including detectors for detecting telegraph signals from received carrier currents and each having low frequency apparatus including amplifiers for amplifying the received signals, and switching arrangements whereby the low frequency apparatus of any channel may be disconnected from its corresponding high frequency apparatus and connected to the high frequency apparatus of any other channel.

3. In a carrier telegraph system, a plurality of carrier receiving channels each having high frequency apparatus including detectors for detecting telegraph signals from received carrier currents and each having low frequency apparatus including amplifiers for amplifying the received signals, and switching arrangements whereby the high frequency apparatus of any channel may be disconnected from its associated low frequency apparatus and connected to the low frequency apparatus of any other channel.

4. In a carrier telegraph system, a carrier transmission line, a carrier receiving channel associated with said line, said channel including a high frequency filter for selecting the carrier frequency assigned to the channel, a detector for translating the selected carrier frequency into low frequency telegraph signals, a low frequency filter for selecting the detected low frequency signals to the exclusion of higher frequencies and a low frequency amplifier for amplifying the selected low frequency signals, said detector and high frequency filter being segregated to form one unit and said low frequency filter and amplifier being segregated to form another unit.

5. In a carrier telegraph system, a carrier transmission line, a carrier receiving channel associated with said line, said channel including a high frequency filter for selecting the carrier frequency assigned to the channel, a detector for translating the selected carrier frequency into low frequency telegraph signals, a low frequency filter for selecting the detected low frequency signals to the exclusion of higher frequencies and a low frequency amplifier for amplifying the selected low frequency signals, said detector and high frequency filter being segregated to

form one unit and said low frequency filter and amplifier being segregated to form another unit, and office cabling intervening between the two units.

6. In a carrier telegraph system, an incoming receiving channel including a detector for detecting telegraph signals from the received carrier currents and an amplifier and amplifying the detected signals, an outgoing transmitting channel including means for supplying a carrier frequency and a modulator to which the carrier frequency is supplied, and means for patching a direct galvanic connection from the output circuit of the detector to the input circuit of the modulator whereby detected low frequency signaling currents may be repeated directly to the modulator without intervening relays.

7. In a carrier signaling system, a plurality of incoming receiving channels each including a detector for detecting low frequency telegraph signals from the carrier frequencies transmitted to the channel, and an amplifier for amplifying the detected telegraph signals, a plurality of transmitting channels each including a modulator, and means for supplying carrier currents to the modulator, and switching arrangements whereby a direct galvanic connection may be established from the output of the detector of any receiving channel to the input of the modulator of any transmitting channel so that telegraph currents detected in that receiving channel may be repeated directly to the modulator of the connected transmitting channel without intervening relays.

8. In a carrier signaling system, a carrier transmission line, a receiving channel associated therewith, said channel including a detector for detecting low frequency telegraph signals from carrier currents transmitted over the line to the channel, said channel also including an amplifier for amplifying the detected signals together with a relay responding to the amplified signals, a second carrier transmission line having a transmitting channel associated therewith, said transmitting channel including a modulator, means for supplying carrier oscillations to the modulator together with a telegraph transmitter for controlling the supply of oscillations to the modulator, and means whereby a direct galvanic connection may be established from the output of the detector in the receiving channel to the input of the modulator in the transmitting channel thereby establishing a circuit whereby repeating may take place between said transmission line section without intervening Morse relays.

9. An amplifying arrangement comprising two vacuum tubes in tandem, a bridge having its terminals connected to opposite poles of a battery whereby an intermediate point of said bridge will be neutral, a connection from the plate of the first of said tubes to a point on said bridge having a positive potential and a connection from the grid of the succeeding tube to a point on said bridge having a negative potential.

10. An amplifying arrangement comprising vacuum tubes in tandem, a bridge arrangement, a pair of batteries having their opposite terminals connected to the terminals of said bridge and their other terminals grounded whereby an intermediate point of said bridge will be neutral, a connection from the plate of the first of said vacuum tubes to a point on said bridge having a positive potential and a connection from the grid of the succeeding tube to a point on said bridge having a negative potential.

In testimony whereof, I have signed my name to this specification this 10th day of July, 1923.

RALPH W. DEARDORFF.