

March 28, 1933.

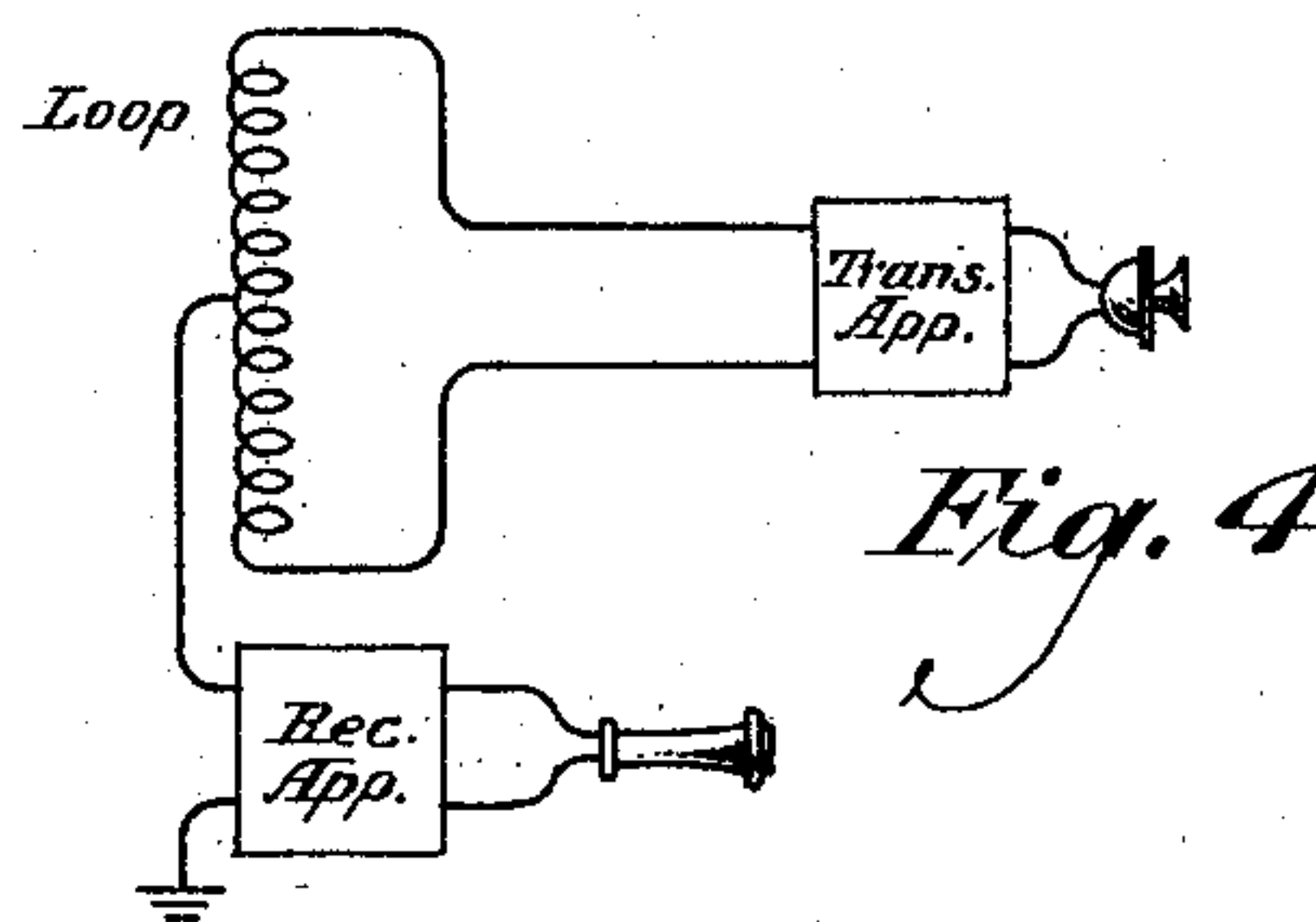
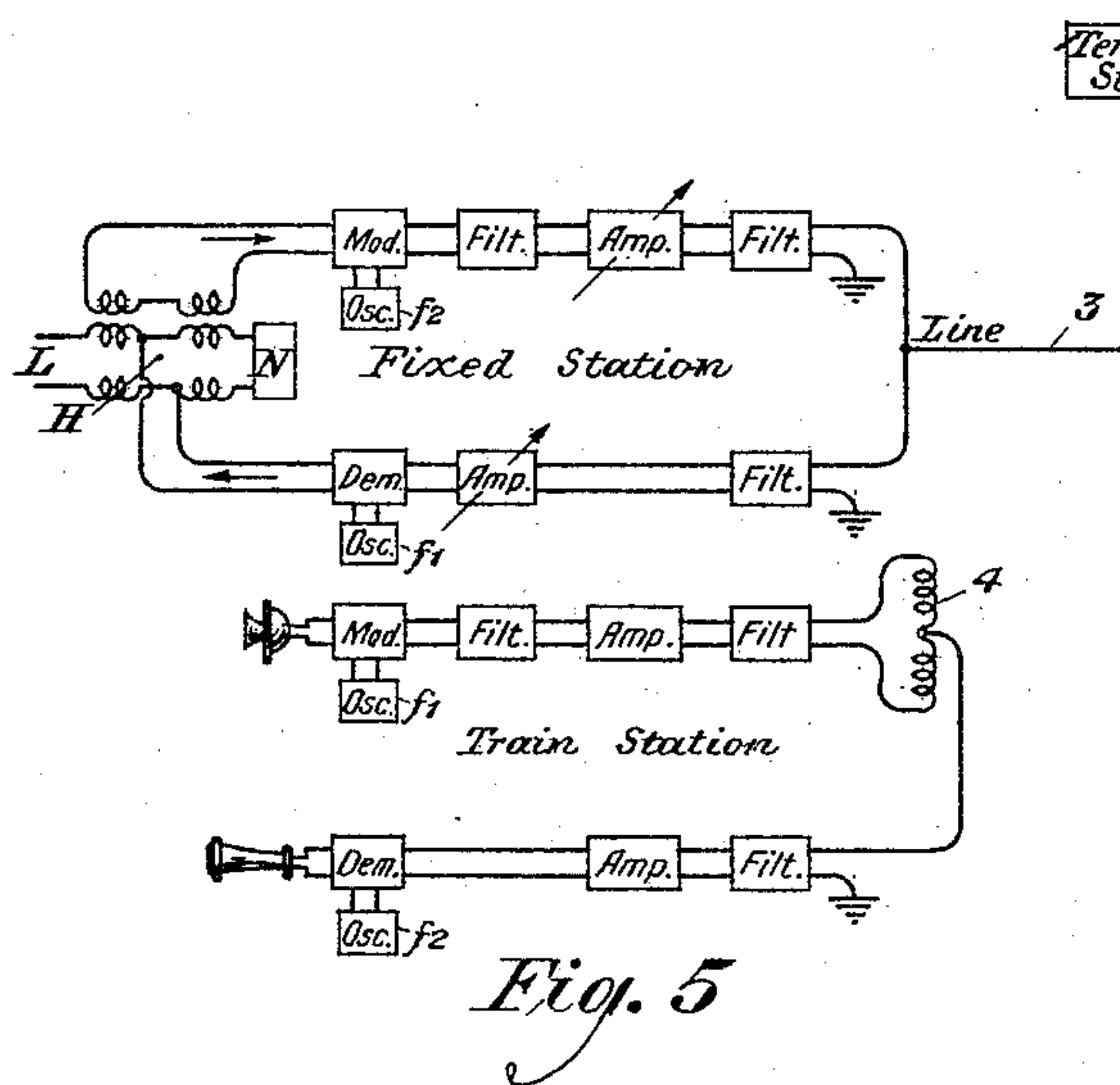
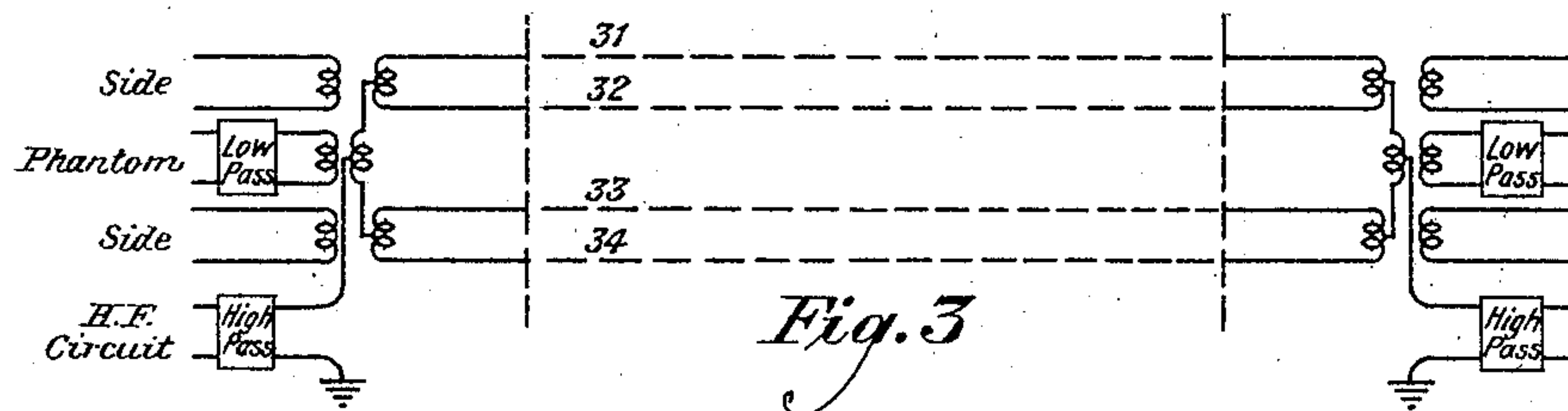
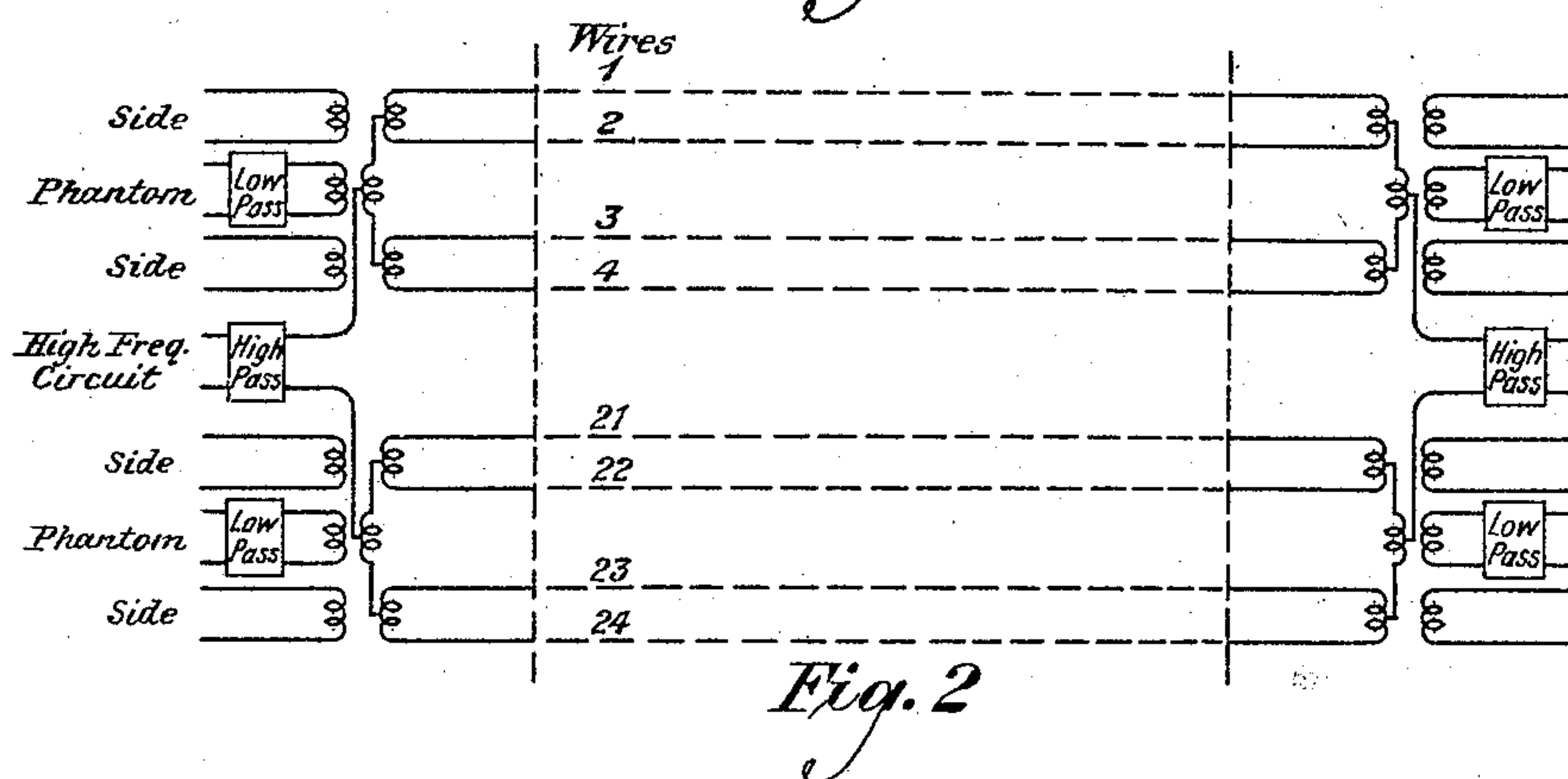
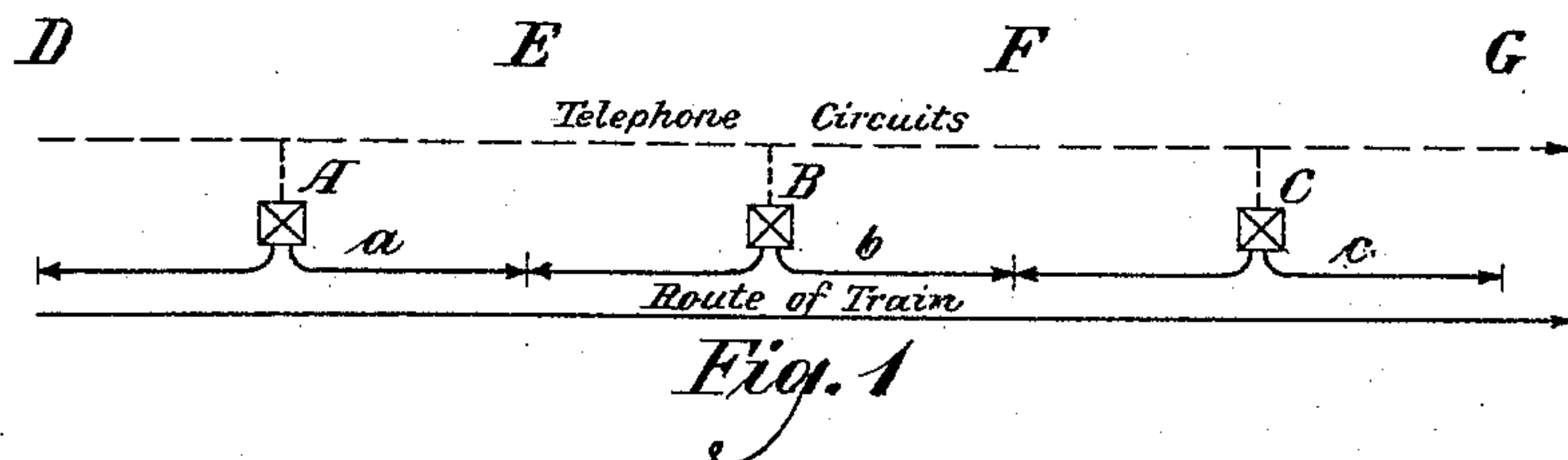
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1,902,817

COMMUNICATION WITH MOVING TRAINS

Filed Oct. 2, 1929

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

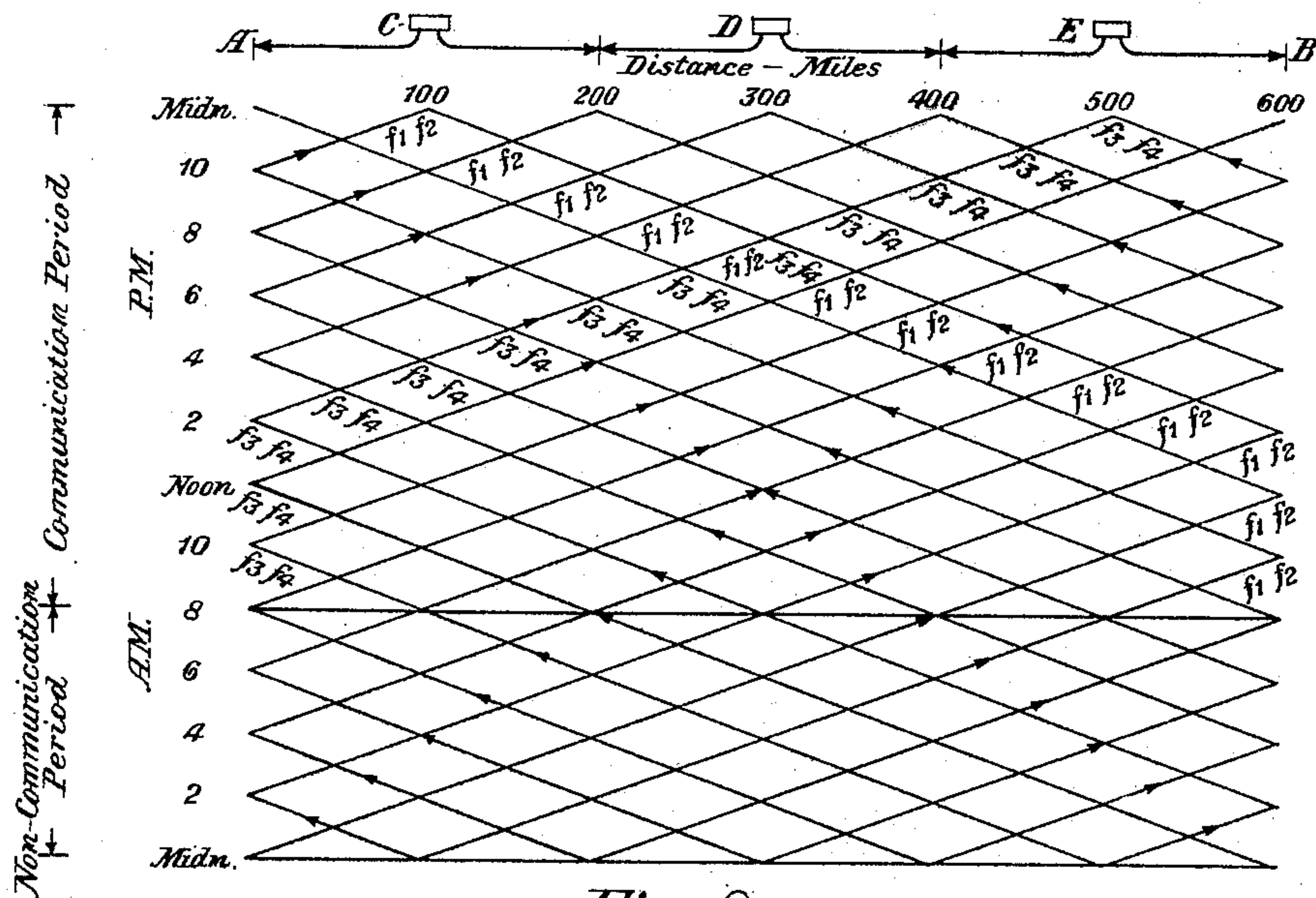
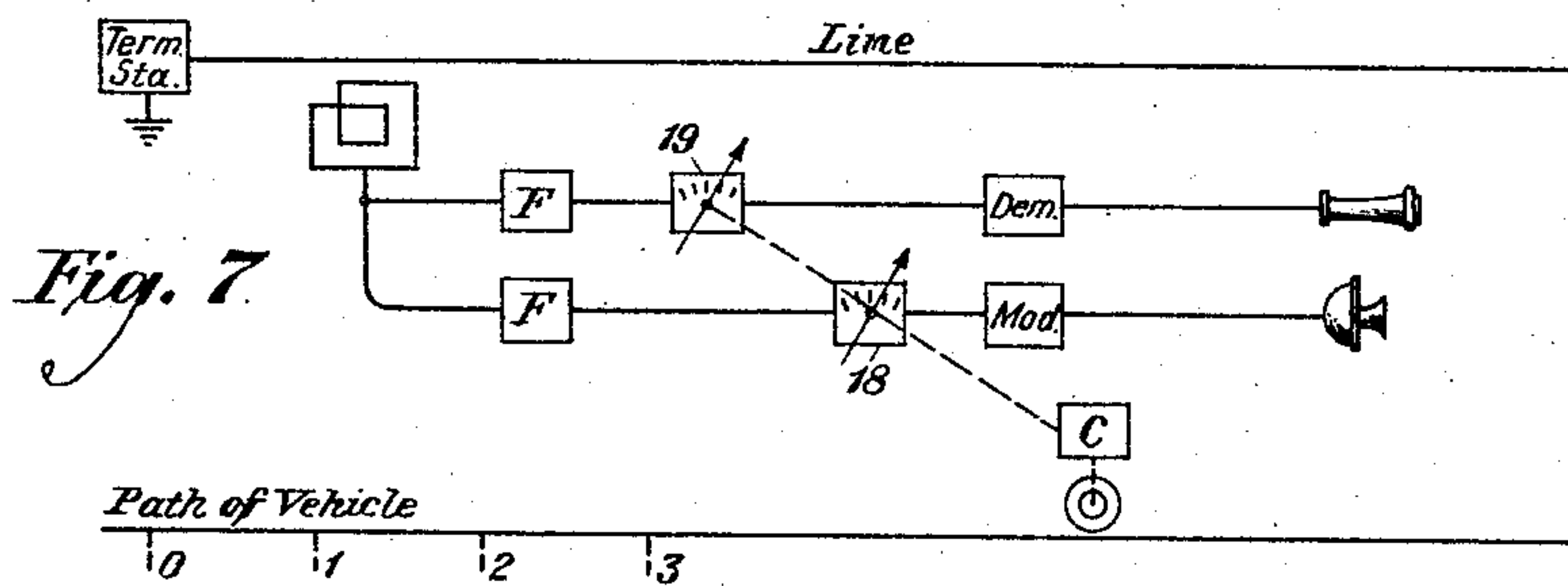
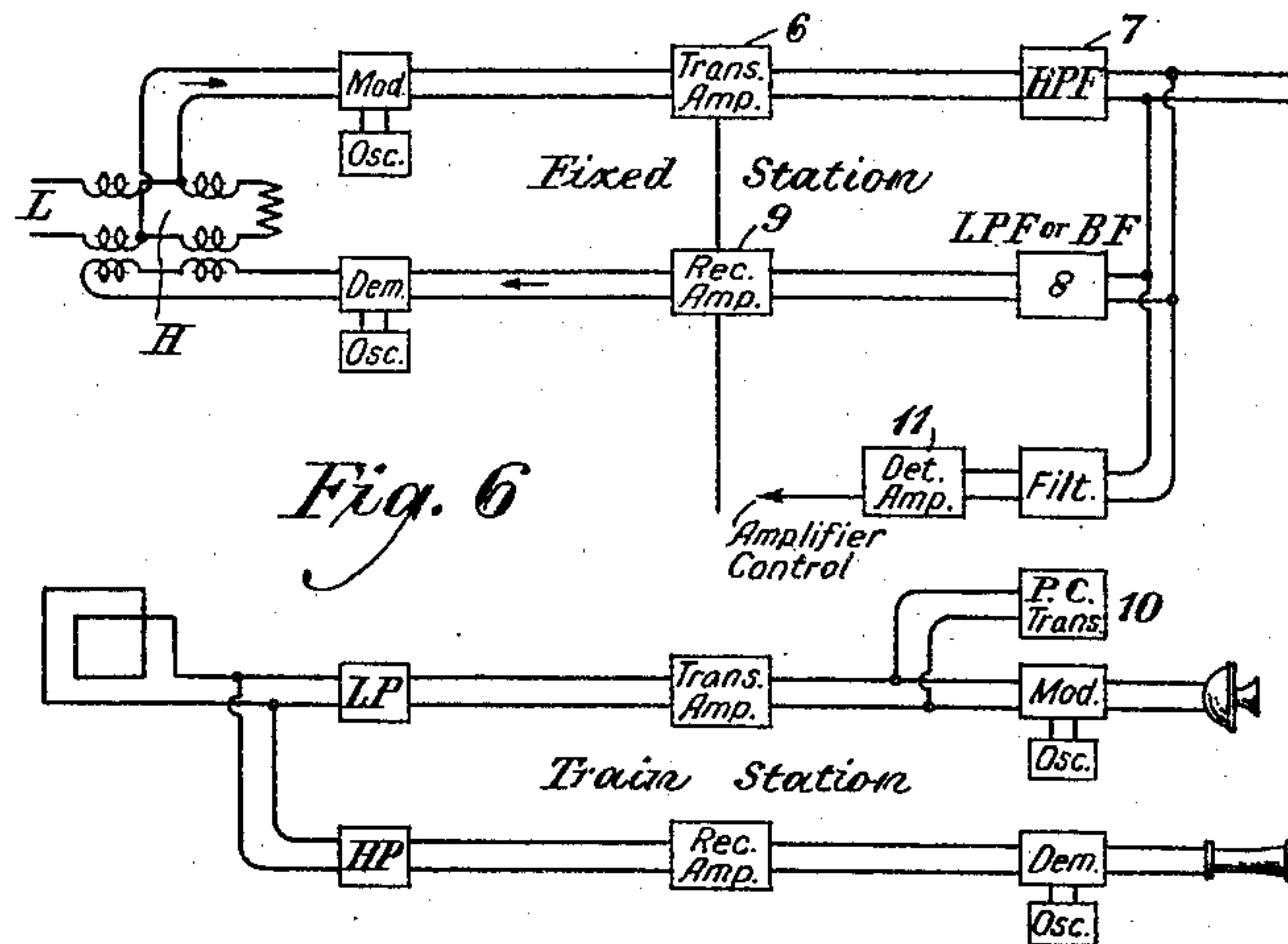


Fig. 8

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COMMUNICATION WITH MOVING TRAINS

Application filed October 2, 1929. Serial No. 396,893.

This invention relates to systems of communication and more particularly to systems for communicating with vehicles in motion, such, for example, as moving railway trains. One purpose of the invention is to make it possible to communicate simultaneously with a considerable number of trains on the same track and to do so with the minimum amount of apparatus and with a minimum use of the frequency spectrum. Another purpose of the invention is to increase the reliability of such communication. Still another purpose is to make the maintenance of the transmission equivalents between the land station and the train automatic and not requiring the special attention of an operator either on the train or the land station.

Briefly, the invention consists in using the existing communication lines, such as telephone or telegraph lines, or other circuits which extend along the railway, and connecting with the moving train by inductive or capacitive coupling across the air gap. The communication line is divided electrically into separate sections of suitable lengths and fixed stations, each transmitting in two directions. The signaling is effected by means of a carrier frequency in order to afford better coupling between the vehicles and the line, and preferably one pair of frequency bands is assigned to each train. The same frequency bands may be employed for trains which do not run simultaneously in the same section.

By locating the division between two sections at appropriate places, such as important cities, it becomes a relatively simple matter to provide telephone connections between a train and any subscriber's station in an expansive telephone system. This means a two-wire termination at the land station but on the train it would be feasible to provide a four-wire sub-set termination, this being possible in view of the limited number of sub-sets involved.

The invention will be better understood by reference to the following specification, taken in connection with the accompanying drawings, in which Figure 1 shows the manner in which a railroad route might be divided

into sections; Figs. 2 and 3 show the manner in which a plurality of telephone or telegraph lines along the right of way may be associated in groups for the transmission of signals; Fig. 4 shows one specific arrangement for transmission between a moving train and the parallel line, making use of combined loop and antenna; Fig. 5 shows in greater detail the arrangement of basic apparatus at a fixed station and a cooperating train station; Fig. 6 is a modification of Fig. 5; Fig. 7 shows provision for compensating for distance of the train from a fixed station; and Fig. 8 gives a schedule arrangement of communication with a large number of trains on the same track with a minimum use of apparatus and frequency spectrum.

The method of transmission which we have found most suitable for such communication is to transmit at carrier frequencies over the telephone line paralleling the track and to use inductive or capacitive coupling for the connection to the train. Such an arrangement is indicated in Fig. 1 in which the line along the track is electrically divided into separate sections *a*, *b*, *c* of reasonable length, say of about 200 miles, it being of course desirable that the various sections shall be of about the same length, although no severe restrictions in this direction are necessary. At or near the center of each of these sections there is located a fixed station, such as A, B, C, adapted to communicate with trains in that section but with no other trains. This station A would provide communication in the section between points D and E, station B between points E and F, and station C between points F and G. It will be noted that this arrangement does not provide any repeaters along the sections but instead of this the sections are made sufficiently short so that any fixed station may communicate directly in both directions with trains in that section. This evidently covers the distance with a minimum amount of apparatus, and we consider this an important feature of our invention. It also furnishes a convenient circuit arrangement since it provides at all times a carrier circuit to the nearest city along the route and from this point voice

circuits can be built up to distant subscribers' stations without difficulty.

In order to avoid confusion during the period when the train is approximately equidistant from two terminals, it may be desirable that the transmitting and receiving frequencies be inverted at alternate stations.

There are a number of ways in which the telephone lines may be associated or used for the present signaling purposes but there are two which we find particularly advantageous. In the one we transmit between two separated wires or groups of wires, and in the second we transmit over a wire or group of wires with ground return. Fig. 2 shows the first of these methods. In this figure it will be seen that the wires 1, 2, 3 and 4 are adapted for ordinary telephonic purposes, being associated further for phantom operation. The same is true of the group of wires 21 to 24. For the purpose of the high frequency signaling now proposed the high frequency current may be sent from either the fixed or the moving station over a metallic circuit, one side of this metallic circuit comprising the lines 1 to 4 and the other side comprising the wires 21 to 24. Suitable high pass and low pass filters are shown in the figures, and by means of these, proper separation is maintained between the high frequency and the low frequency signal channels.

In Fig. 3 a group of wires 31 to 34 is used as one side of the high frequency circuit and the ground is used for return. Again suitable high pass and low pass filters are provided to maintain separation between the different signaling channels.

In order that the message shall not be picked up unnecessarily by other telephone or telegraph lines adjacent to those which are being used, it may be desirable to introduce into these additional lines suitable loading or choke coils which will prohibit the flow of the high frequency signals.

As stated above, we employ some form of inductive or capacitive coupling with the train. We have found that approximately the same transmission loss is involved with either form of coupling and it may therefore be desirable to use a combined loop and antenna, that is, to use the inductance of a loop for the transmitter coupling and its capacity to ground for the receiving coupling, or the reverse. Such an arrangement is shown in Fig. 4, in which transmission from the train takes place over a loop, that is, by inductive coupling, whereas reception takes place over the loop considered as an antenna, that is, by capacitive coupling. This mode of operation has an advantage in that it greatly reduces the transmission loss which would otherwise be required in the receiving filter to discriminate against the transmitting frequency range.

A more detailed drawing of the arrange-

ment of apparatus at the fixed station and the train station is shown in Fig. 5. The line L is connected with any remote subscriber's station, and by means of the hybrid coil H is adapted in the well known manner for two-way communication. Incoming low frequency signals over the line L are used to modulate a carrier frequency f_2 and, on suitable amplification with protecting filters, is impressed upon the line 3 paralleling the track which may be the plurality of conductors of Figs. 2 and 3, in this case the line acting as an antenna or one side of the transmission channel and the ground being used for return. At the train station such signals are picked up on the loop 4 acting as an antenna and are transmitted through suitable filters and amplifiers to a demodulator supplied with the same carrier frequency f_2 . For signaling in the reverse direction the microphone currents at the train station are impressed upon a modulator supplied with carrier frequency f_1 and after transmission through suitable protecting filters and amplifiers is impressed on the loop 4. The signals being picked up by the line 3 are then amplified and impressed on a demodulator supplied with a carrier frequency f_1 and the demodulated product is then transmitted over the line L.

As the train travels along there will be large and often very sudden changes in transmission due to the following causes:

- (1) Changes in separation between the train and the paralleling line.
- (2) Changes in a vertical direction in the position of the coupling device with reference to the line.
- (3) The presence of another train between the coupling device and the line.
- (4) Varying distance from the fixed station. Some of these variations may be eliminated or reduced by using two collecting sources on the train, one at the front and one at the rear. This is especially helpful in the case of the short departures of the line from the track such as when the line enters a dispatcher's station. In any event, however, we find it important that a pilot channel shall be provided to stabilize the transmission. Fig. 6 shows a fixed and a moving station with a schematic pilot channel for the purpose described. In this figure there is shown a two-wire termination for the land station, the hybrid coil H making it possible to carry on two-way signaling with a remote subscriber's station. The low frequency incoming signal is modulated against a locally generated high frequency carrier, the modulated signal then being amplified at the transmitter-amplifier 6 and impressed on the transmission line through the high pass filter 7. Modulated high frequency signals coming from the train are transmitted through the low pass or band filter 8 and the receiver-

amplifier 9, thereafter being demodulated and impressed on the line L. A precisely similar equipment is provided on the train station.

5 In order to obtain transmission level control we provide a pilot channel consisting of a carrier frequency transmitted from the one station to the other and preferably of a frequency near but not in the signaling band. 10 In Fig. 6 there is shown at the train station at 10 a pilot control transmitter consisting of means for impressing on the line the pilot signal. This signal is picked up at the fixed station and transmitted through suitable filters and a detector-amplifier 11, the output 15 of this amplifier being used to control the gain in the amplifiers 6 and 9 by any suitable means. While this pilot signal has been shown as being transmitted from the train station, it is obvious that it might be transmitted in the reverse direction but we find it preferable to have most of the apparatus for the pilot channel located at the fixed station since it is desirable to have as little apparatus 25 as possible on the train, and it is thus described in the figure. It should be pointed out, however, that with several fixed stations it may be more advantageous to locate the pilot channel receiving apparatus on the train. We do not here describe the operation of the pilot channel control in detail, any appropriate apparatus being permissible such, for example, as that described in patent to Clark, No. 1,438,219, of December 12, 35 1922. However, because of the speed of the train the pilot channel should have almost instantaneous response to large transmission changes and this we find can best be obtained by varying either the B battery on the amplifier tubes or the grid voltage on the modulator tubes, or both. This may be accomplished in any well known manner, such, for instance, as by adding to the regulation battery supply a variable positive potential applied to the grid or a varying negative potential applied to the plate, these potentials varying directly with the rectified current received on the pilot channel. Such methods of control are described in patents to Affel, 50 1,511,015, of October 7, 1924, or 1,574,780, of March 2, 1926.

The pilot channel arrangements thus described are intended primarily to take care of the variations coming under items 1, 2 and 3 of page 6. It might also be used for taking care of the variations coming under item 4; that is, the changes due to varying distance between the train and a fixed station, which changes will occur gradually. Since 60 it may be difficult to take care of all variations with the pilot channel, it will be desirable to relieve the pilot channel as much as feasible and to this end we find that the variation in transmission level due to varying distance between the train and the fixed station

may be compensated by an arrangement similar to that shown in Fig. 7. This arrangement provides, on the train, transmitting and receiving potentiometers 18 and 19 which are mechanically connected to a device which in turn is geared to the wheels. This device is 70 arranged to make contact at various intervals along the route and thus move the potentiometers up or down one step according to whether the train is leaving or approaching the fixed station. The points 1, 2 and 3 on 75 the path of the vehicle are so spaced that the distance between points equals the total span covered by a single station divided by the total number of potentiometer steps. A switch or other device set at the beginning of the trip will arrange it so that the gain is increased or decreased as desired. Obviously, many variations on this may be conceived, for example, instead of being operated on a 80 mileage basis by virtue of being geared to the wheels, the potentiometer control might be operated by fixed devices set at suitable points along the road bed, these taking the form of projecting arms, third rails, or other special arrangements. 85 90

The system as described may be operated with a single carrier frequency for both transmission and reception or with two different carrier frequencies f_1 and f_2 , one for transmission and the other for reception. The second method has the advantage of more definite separation of the transmitted and the received signals, with corresponding simplification of the terminal apparatus, but it uses 95 twice as much of the frequency spectrum. 100

Thus far the description of our invention has related to communication with a single train, but an important part of the invention consists in making provision by which communication to a large number of trains is possible. The system thus far described lends itself especially well to this inasmuch as it is one in which the amount of apparatus is kept to a minimum. A number of methods are available for such communication with a plurality of trains. One method which we contemplate is that of providing a number of different communication channels and arranging for each train to select an idle 110 channel. The procedure would be analogous to that in general telephone practice where a group of circuits is provided between two cities, from which the operator selects an idle circuit. In our system, for example, if communication were desired with twenty trains, it would be necessary to establish four or five communication channels. It is evident, however, that this arrangement requires elaborate and expensive equipment on each train 120 in order to make it possible to select any one of the available channels. For example, the equipment needed for ringing individual trains we find becomes rather complicated. 125

A second method which we contemplate 130

for our invention, and which provides for better economy and simplicity, would make use of a different pair of frequencies for each train. This method is practicable for a small number of trains, but as the total number of trains on a given line is increased, the problem of finding suitable frequency bands sufficiently separated in that portion of the frequency spectrum where the attenuation would not be excessive, becomes difficult. Furthermore, the apparatus at the fixed stations would become complicated if each of them is equipped to signal on so large a number of carrier frequencies.

A third and preferred method which we find especially well adapted for the case of a large number of trains is to assign each train one, and only one, pair of frequencies, but to use the same pair of frequencies for several different trains. It will be clear that any two trains which do not run simultaneously in the same line section can use the same pair of frequencies without mutual interference. Hence, the total number of pairs of frequencies necessary in any line section is equal to the maximum number of trains running simultaneously in that section at a given time, and the assignment of frequencies to the different trains then becomes a relatively simple matter.

Consider, for example, the illustration in Fig. 8. This represents a diagram of the running schedule for a theoretical railroad line covering a distance of 600 miles between two cities A and B. Let us assume that twelve trains a day are run in each direction between these two towns, the trains leaving the terminals on the even hours. The running time for each train is taken as twelve hours. The schedule is drawn by plotting distances traveled as abscissæ, and times as ordinates. In the diagram, the twenty-four hour period is assumed to be divided into a period from 8:00 A. M. to midnight during which communication is provided, and the period from midnight to 8:00 A. M. during which communication is unnecessary. The exact length of this period is, of course, immaterial. The total distance of 600 miles is divided into six sections of 100 miles each, and it is assumed that each of the fixed stations located at C, D and E will maintain communication for 100 miles on either side.

In this simple illustration none of the trains going from A to B runs simultaneously in the same section with the preceding or the following train. Hence, all the twelve trains in the A—B direction can use the same pair of frequencies f_1 and f_2 . Similarly, all of the trains running in the B—A direction may use a common pair of frequencies, but since these trains run simultaneously in the same section with trains going in the A—B direction, this must be a new pair of frequencies f_3 and f_4 . At each of the fixed sta-

tions apparatus for both pairs of frequencies is necessary. From the above it is seen that a total of only four frequencies is required for maintaining communication with twenty-four trains, and each train is assured of a free channel at all times and the apparatus at the fixed stations is used with maximum efficiency. It may be noted in comparison that the second method proposed above would require a total of forty-eight different frequency bands.

If the total number of trains in the assumed system were doubled, one train leaving each terminal every hour, then successive trains in each direction would run simultaneously in the same line section. In this event it would be necessary to use a different pair of frequency bands for alternate trains, and the total number of pairs of bands required would be eight instead of four. As an alternate solution of this last situation it is evident that the fixed stations, could be placed closer together in order to avoid the contingency of two trains, with which communication is to be maintained, being in the same section.

In general, the procedure would be to set up a diagrammatic schedule of the type illustrated in Fig. 8 and from this determine for each direction of travel the trains which run simultaneously in any one section. The proper assignment of frequencies for one direction then becomes obvious. A certain factor of safety may be required because the trains cannot always run on schedule, but this means only the addition of a small number of frequency bands or a reduction in the length of the sections.

While this system of communication has been described in a certain specific manner, it is to be understood that the scope of the invention covers many variations therefrom. For example, while it has been specifically stated that a pair of frequency bands is preferred for each train, one for transmission and one for reception, it is to be understood that such two-way signaling may be maintained on one frequency band. Also, while in Fig. 8 the trains are indicated as running through the length of the railway line with uniform speed, such will frequently not be the case, and a correct diagram for any train would show a slope of the line which changes from one portion to another in accordance with the speed of the train over a given portion of the line.

What is claimed is:

1. In a signaling system to and from moving trains, a transmission line along the route of the trains, means for electrically dividing said line into a plurality of sections, a fixed carrier frequency signaling station near the middle of each section and associated for two-way signaling with the transmission line, and a plurality of trains each provided with inductive means for two-way signaling with

said line, each train in a section being provided for signaling on a different pair of carrier frequencies and each fixed station being equipped for signaling simultaneously on the pairs of carrier frequencies associated with the plurality of trains.

2. In a system for signaling to and from moving trains, a transmission line along the route of the trains for transmitting signal current, means for electrically dividing said line into a plurality of sections, a fixed carrier frequency signaling station near the middle of each section and associated for two-way signaling with the transmission line on a plurality of carrier frequencies, means thereat for modulating the carrier frequency with the signal current and a plurality of trains provided with means for two-way signaling with said line, means at each fixed station to provide a separate pair of carrier transmission frequencies for each train which may simultaneously be in its section.

3. In a system for signaling to and from moving trains, a transmission line along the route of the trains, means for electrically dividing said line into a plurality of sections, a fixed carrier frequency signaling station near the middle of each section and associated for two-way signaling with the transmission line, a train provided with means for two-way signaling with said line, and means for controlling the transmission level of the signals in accordance with the distance to the fixed station and in accordance with variations in the coupling between the train and the transmission line.

4. In a system for signaling to and from moving trains, a transmission line along the route of the trains, means for electrically dividing said line into a plurality of sections, a fixed carrier frequency signaling station near the middle of each section and associated for two-way signaling with the transmission line, a train provided with inductive means for two-way signaling with said line, a pilot signaling channel for indicating the transmission level of the communication circuit, and means responsive to said indications for controlling the gain.

5. In a system for signaling to and from moving trains, a transmission line along the route of the trains, means for electrically dividing said line into a plurality of sections, a fixed carrier frequency signaling station near the middle of each section and associated for two-way signaling with the transmission line, a train provided with inductive means for two-way signaling with said line, and means at the train for controlling the gain in accordance with the distance to the fixed station and means at the latter to control the gain in accordance with the variations in coupling.

6. In a system for signaling to and from moving trains, a transmission line along the

route of the trains, means for electrically dividing said line into a plurality of sections, a fixed carrier frequency signaling station near the middle of each section and associated for two-way signaling with the transmission line, a train provided with inductive means for two-way signaling with said line, a pilot signaling channel for indicating the transmission level of the communication circuit, means at the fixed station to control the transmission gain in accordance with the variations in coupling, and further means at the train for controlling the gain in accordance with the distance to the fixed station.

7. In a system for signaling to and from moving trains, a fixed signaling station at one point along the route adapted for two-way signaling, a train provided with means for two-way signaling with said fixed station, a pilot signaling channel for indicating the transmission level of the communication circuit, and means at one of the stations to control the transmission gain in accordance with the variations in coupling.

8. In a system for signaling to and from moving trains, a transmission line along the route of the trains, a fixed signaling station at one point along said route adapted for two-way signaling with the transmission line, a train provided with means for two-way signaling with said line, a pilot signaling channel for indicating the transmission level of the communication circuit, and means responsive to said indications for controlling the gain of said communication circuit.

9. In a system for signaling to and from moving trains, a section of transmission line along the route of the train, a fixed carrier frequency signaling station near the middle thereof and associated with the transmission line for signaling, a train provided with means for signaling with said line, and means for controlling the transmission level of the signals in accordance with the distance to the fixed station and in accordance with variations in the coupling between the train and the transmission line.

10. In a signaling system to and from moving vehicles and comprising a transmission line along the route of vehicles, the line being electrically divided into a plurality of sections, a fixed carrier frequency signaling station near the middle of each section and associated for two-way signaling with the transmission line and inductively coupled to the vehicles, carrier frequency transmitting and receiving apparatus on each train, each train operating on a pair of carrier frequencies one for incoming and one for outgoing signals, means for adjusting the carrier frequency so that each train in any one section operates on a pair of carrier frequencies different from that for the other trains in that section, the trains in any other section being adapted to use the same sets

of carrier frequencies as in the first named section.

11. In a signaling system to and from moving vehicles and comprising a transmission line along the route of vehicles, the line being electrically divided into a plurality of sections, a fixed carrier frequency signaling station near the middle of each section and associated for two-way signaling with the transmission line and inductively coupled to the vehicles, carrier frequency transmitting and receiving apparatus on each train, each train operating on a pair of carrier frequencies one for incoming and one for outgoing signals, means for adjusting the carrier frequency so that each train in any one section operates on a pair of carrier frequencies different from that for the other trains in that section, the same pairs of carrier frequencies being used on all sections and each section being electrically isolated from the other sections for carrier frequency signals.

12. In a system of signaling to and from moving trains comprising a transmission line along the route of the trains for audio frequency signaling between widely separated points and fixed signaling stations along the line, the method of signaling which consists in sending the audio frequency message along the transmission line to the fixed station nearest the train, converting the message to a modulated carrier wave, impressing this carrier wave on the transmission line, receiving the message inductively on the train, and converting it to normal audio frequency.

13. In a signaling system to and from moving vehicles, a transmission line along the route of the vehicles, means for electrically dividing said line into a plurality of sections for frequencies above the audio-frequency-range, a fixed carrier frequency signaling station near the middle of each section, means for two-way transmission of audio frequency messages on said transmission line between any fixed station and a remote point, means at any one of the fixed stations for converting the message to a carrier frequency wave and for impressing the wave on the section of the transmission line adjacent the fixed station for reception by a train in that section.

14. In a signaling system to and from moving vehicles, a transmission line along the route of the vehicles, means for electrically dividing said line into a plurality of sections for frequencies above the audio-frequency range, a fixed carrier frequency signaling station near the middle of each section, means for two way transmission of audio frequency messages on said transmission line between any fixed station and a remote point, means at any one of the fixed stations for converting the message to a carrier frequency wave and for impressing the wave on the section of the transmission line adjacent the fixed station

for reception by a train in that section, and means at the end of each section to limit the carrier frequency to that section.

15. In a system for signaling to and from moving trains, a fixed station at one point along the route adapted for two-way signaling, a train provided with means for two-way signaling with said station, a gain control device comprising amplifiers connected in the train circuit and means for increasing the gain of the amplifiers, said means being controlled automatically by the rotation of the train wheels to adjust the gain in accordance with the distance from the nearest fixed station.

In testimony whereof, we have signed our names to this specification this 27th day of September, 1929.

HERMAN A. AFFEL.
ESTILL I. GREEN.