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MULTIPLEX SIGNALING SYSTEM

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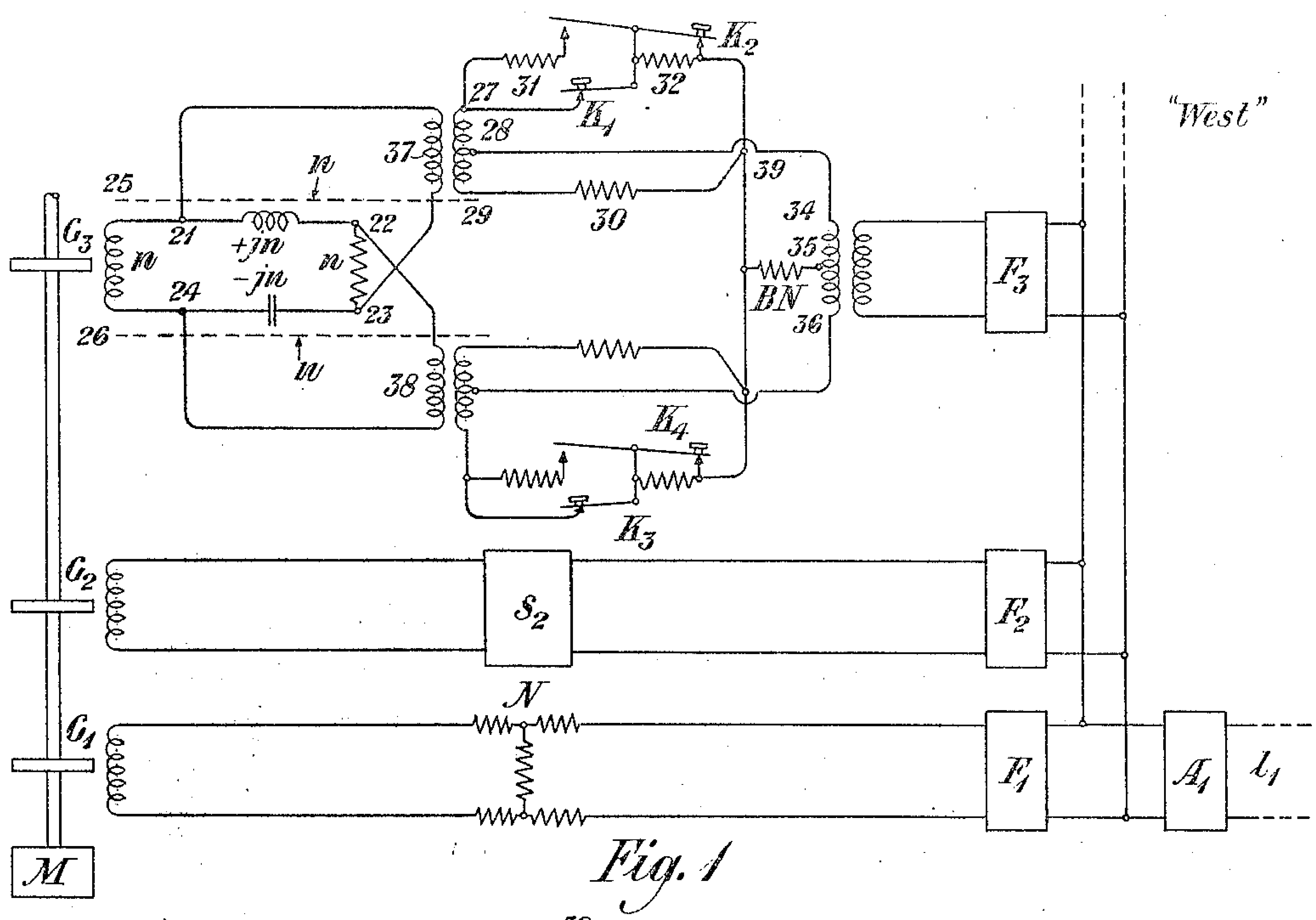

Fig. 1

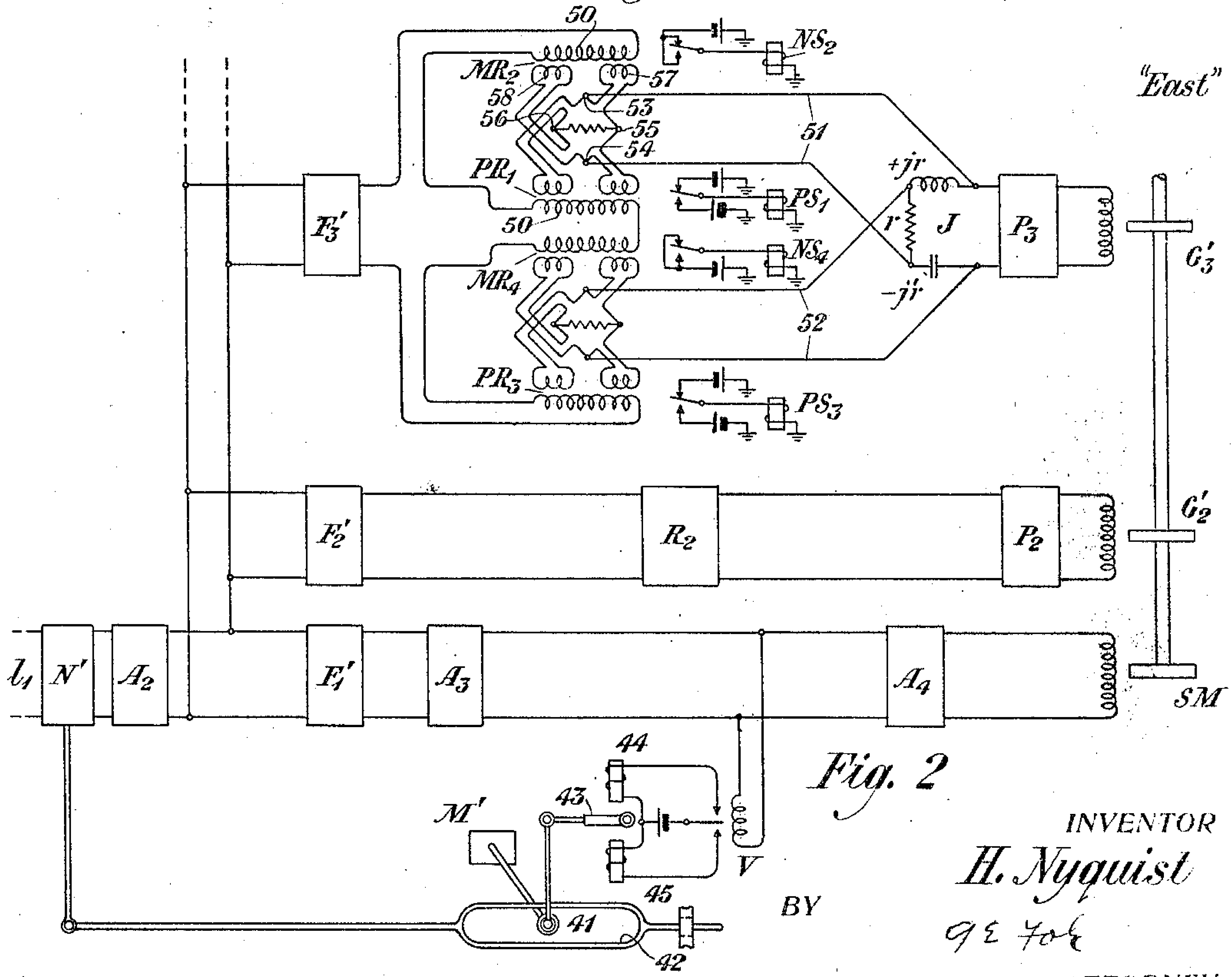

Fig. 2

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UNITED STATES PATENT OFFICE.

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MULTIPLEX SIGNALING SYSTEM.

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An object of my invention is to provide a new and improved method and suitable apparatus for utilizing a line for the simultaneous transmission of a number of messages. Another object of my invention is to provide for a system of multiplex telegraphy with discrimination by difference of phase between messages in the same frequency range. Still another object of my invention relates to providing for magnitude discrimination as well as for phase discrimination between different messages transmitted within the same frequency range. Still another object of my invention is to provide suitable apparatus and method for receiving messages superposed on a carrier current and depending on phase discrimination or magnitude discrimination, or both, to distinguish them. These and various other objects of my invention will become apparent on consideration of a specific example of practice according to the invention, which I have chosen to illustrate and describe in this specification. With the understanding that the following disclosure relates to this particular example of the invention and that the scope of the invention will be indicated in the appended claims, I now proceed to describe the structure and mode of operation of the apparatus shown in the drawings.

Figure 1 is a diagram of multiplex carrier current sending equipment, and Fig 2 is a diagram of the corresponding receiving equipment.

At the station "West" shown in Fig. 1, the constant speed motor M drives the inductor alternators, of which three are shown, G_1, G_2 and G_3, of different "carrier current" frequencies. The output current from the generator G_3 goes over the circuit 21—22—23—24 through an inductance coil of impedance $+jn$, a resistance n and a condenser of impedance $-jn$ in series, where n has any suitable value, say 600 ohms. The value n is the resistance of the generator G_3 looking into it across the points 21, 24 and it is important in the particular example illustrated that the impedance of the generator should be substantially a pure resistance as seen from its output terminals. The network 21—22—23—24 is a balanced Wheatstone bridge because the product of the impedance of one pair of opposite arms is equal to the corresponding product for the other pair of opposite arms. Hence there is no interference in the transformer winding 37 due to electromotive force in the winding 38, nor vice versa. This is true for the particular frequency of the generator G_3. It is also true for other frequencies because with a variation of frequency the impedance of the coil and the impedance of the condenser will vary inversely and, therefore, their product will be constant, and equal to $(+jn)\ (-jn)=n^2$.

Looking across the circuit at 25 in the direction of the arrow, the impedance is n; this is true because the circuit of the coil 38 may be considered open on account of the bridge balance, and it follows that the impedance between the points 21 and 23 is

$$\frac{(n+jn)(n-jn)}{(n+jn)+(n-jn)}=n.$$

The currents in the windings 37 and 38 are 90 degrees apart in phase. To prove this, notice that if a given voltage is impressed across the points 21 and 23, the current into the generator will lead by 45 degrees. The design is such that the impedance across the terminals of the coil 37 is effectively a pure resistance. This being the case, it follows that the current in the winding 37 due to a voltage from the generator G_3 will lead by 45 degrees. Similarly, it can be shown that the current due to the generator G_3 in the winding 38 will lag 45 degrees, and hence the currents in the windings 37 and 38 are 90 degrees apart.

To explain the operation of the keys K_1 and K_2 in Fig. 1, first assume that the keys and the resistances 31 and 32 are removed and that the points 27 and 39 are connected by a resistance equal to the resistance 30. The points 28 and 39 will then be neutral points, no matter what current flows in the winding 37, and there will be no transmission. It will readily be seen that while the key K_2 remains closed, the key K_1 gives zero resistance from 27 and 39 when it is closed for marking and infinite resistance when it is open for spacing. As is well known, when two unequal resistances are joined, it is permissible and often convenient to look at the point of junction as a point of reflection and to consider that there is a reflected current wave at the point of junction. In the case here under consideration, the reflected wave from point 27 is transmitted in part into the line. It is also well known that in the limiting case when one of the resistances is made zero and the other is left finite, the inflected current is equal to and in phase with the incident current, whereas in the limiting case when one of the resistances is made infinite and the other is made finite, the reflected current is equal to and in phase opposition to the incident current. If, therefore, the impedance at 27 is changed from zero to infinity, the effect is to reverse the current transmitted to the line. Now if a resistance artificial line is connected between point 27 and the point of reflection and if this artificial line is so designed that there is no reflection at point 27, then the incident wave will traverse the network and be attenuated; moreover, the reflected wave will traverse the line also. The net result of the artificial line is that the current transmitted to the transmission line is attenuated by twice the loss of the artificial line. While the function of the key K_1 is to open and close the circuit and thus to reverse the phase of the transmitted current, the function of key K_2 is to add or remove artificial line and thus to change the magnitude without changing the phase.

Thus it will be seen that the key K_1 transmits by phase reversal of the carrier current and the key K_2 transmits by changing the magnitude of one component of the carrier current from generator G_3.

In a similar manner, the keys K_3 and K_4, respectively, transmit by phase reversal and magnitude change in the other carrier current component which differs 90 degrees in phase from that controlled by the keys K_1 and K_2. These two carrier current components of the same frequency, differing 90 degrees in phase and varying in magnitude as determined by the operation of the keys K_2 and K_4, are superposed in the input of the band filter F_3 whose output goes in multiple with the outputs from other similar filters to the line l_1. These filters are confluent band filters each with relatively narrow band width and with the carrier frequency near the middle of its range so as to produce no serious phase shift during the building up of the signals.

The box S_2 represents a network similar to that between the generator G_3 and the filter F_3. Accordingly, four more messages will be carried in the channel from the generator G_2 through the network S_2 and the filter F_2 and added in multiple on the line l_1.

Alternating current of still another frequency from the generator G_1 is passed through the artificial line or network N, by which it is reduced to the proper intensity to be put on the line. The simple unmodulated current of desired intensity goes from the network N through the filter F_1 and terminal repeater or amplifier A_1 to the line l_1.

As shown in Fig. 1, three frequency channels are provided in the line l_1. Two of these, identified respectively with the generators G_3 and G_2, each carry four messages. The frequency in the third channel, identified with the generator G_1, may be called a pilot frequency and the channel may be called a pilot channel. As will be pointed out presently, this channel is utilized to provide for synchronism at the receiving end.

Referring to Fig. 2, this shows the receiving station which may be called "East". The currents coming in over the line l_1 pass through the adjustable artificial line or network N′, which is controlled automatically in a manner to be described presently. This net work N′ attenuates the currents so as to give a uniform magnitude in its output for the same signal elements from one time to another. The currents, thus attenuated to a standard magnitude, pass through the amplifier or terminal repeater A_2 to the band filters F'_1, F'_2, and F'_3 in multiple. These filters correspond in their frequency ranges, respectively, with the filters F_1, F_2 and F_3 at station "West".

The current of pilot frequency goes through the filter F'_1 to the amplifier A_3 and thence to a power tube amplifier A_4 whose output goes to the synchronous motor SM, which drives the two generators G'_2 and G'_3 of the same frequency, respectively, as G_2 and G_3 at station "West."

The voltmeter relay V is connected across the output from the amplifier A_3 and normally holds its index at a certain position corresponding to a certain voltage. Whenever this voltage changes a little either way, the index closes one or the other of the circuits for the magnets 44 and 45, causing the armature 43 to move and bring the wheel 41 in contact with one side or the other of the yoke 42. The wheel 41 is rotated continuously by the motor M′ so that the artificial line N′ is adjusted one way or the other to adjust the attenuation therethrough. Thus it will be seen that by means of the voltmeter relay V and the associated apparatus, the current of pilot frequency is kept at uniform voltage as delivered to the input of the amplifier A_2. This insures that for the same signal elements in the other channels, the voltages delivered to the input of the amplifier A_2 will be uniform. Even if the attenuation on the line l_1 varies from time to time, as may be the case due to weather conditions, etc., there will be no corresponding variation of the current and voltage magnitudes in the output from the network N′ at station "East." If the received currents at "East" were to vary from time to time, it might happen that signals of low magnitude would sometimes be strong enough to affect the low magnitude receiving apparatus or that high magnitude would sometimes be too weak to affect the high magnitude receiving apparatus. By the adjustment of N′ any such outcome is prevented.

The modulated current of carrier frequency determined by the generator G_3 at station "West" will accordingly find its way through the filter F'_3 to the windings 50 of the alternating current relays to be described presently.

There are four of these relays, PR_1, MR_2, PR_3 and MR_4. Each of them is of the dynamometer type comprising two members each energized by alternating current and relatively movable. In the relay MR_2 the winding for one member is 50 and the winding for the other member comprises the two coils 57 and 58. As will readily be seen, the winding 50 carries the received carrier current of a certain frequency comprising two phase components each modulated by phase reversals and by magnitude changes.

The current in the coils 57 and 58 is generated locally. The generator G'_3 is of the same frequency as the carrier belonging to the band passed by the filter F'_3. The output current from this generator goes through an adjustable phase shifter P_3 and then through a phase splitter J whose principle is the same as that at the station "West" associated with the generator G_3.

In the output circuits 51—52 from the phase splitter J the currents are 90 degrees apart. The conductors 51 go to two opposite vertices 53 and 54 of a Wheatstone bridge whose other two vertices 55 and 56 are joined by a resistance. The dynamometer windings 57 and 58 of the relay MR_2 are in two opposite arms of the bridge and the corresponding windings of the relay PR_1 are in the two remaining opposite arms of the same bridge.

The bridge arrangement makes the operation of either relay PR_1 or MR_2 independent of any reaction involved in the operation of the other of these relays.

The current delivered by the conductors 51 will be in phase with one of the two carrier components from the filter F'_3 and 90 degrees from the other. The currents in phase in the windings 50 on the one hand and 57, 58 on the other hand, will produce effective armature movement if of sufficient magnitude, but the currents 90 degrees apart will tend to produce movements only of the carrier frequency to which the armature will be much too slow to respond effectively. Moreover, the relay MR_2 is marginal and adjusted so that in the absence of current its armature stands midway between the two contacts shown and it will only close on one or the other of these contacts when current is of the intensity determined by the closure of the key K_2 at station "West." Phase reversals as determined by the key K_1 at "West" will merely shift the armature quickly from one contact to the other as long as the key K_2 remains closed. The relay MR_2 controls a neutral sounder NS_2.

The relay PR_1 is like the relay MR_2 except that its armature is thrown one way or the other by current of any magnitude. On one contact the armature applies positive current to the polar sounder PS_1 and on the other contact it applies negative current. Thus it will be seen that the armature of the relay PR_1 responds to the operation of the key K_1 at station "West" independently of the current magnitude as determined by the key K_2.

From the description that has gone before, it will readily be seen how the other phase component of the received carrier current operates the polar relay PR_3 according to phase reversals as determined by the key K_3 at station "West" and how it operates the marginal relay MR_4 as determined by the key K_4 at station "West." The corresponding messages are ultimately received in the respective polar sounder PS_3 and neutral sounder NS_4.

I claim:—

1. Means to receive alternating current signals with discrimination as to phase, comprising dynamometer relays each having one of its windings energized by the received current, means to generate locally currents of the same frequency and of the respective phases, Wheatstone bridges to which these locally generated currents are applied, and conductors from opposite sides of each bridge to the remaining windings of the respective dynamometer relays.

2. Means to receive and discriminate signals on different phases and different magnitudes of alternating carrier current of a certain frequency, comprising dynamometer relays each with one winding energized by the received current and each with another winding energized by local current in phase with a desired component of the received current, one such relay being marginal.

3. Means to receive and discriminate signals on different phases and different magnitudes of alternating carrier current of a certain frequency, comprising dynamometer relays each with one winding energized by the received current and each with another winding energized by local current in one circuit in phase with a desired component of the received current, and means to prevent resultant reaction through said circuit from one relay to another.

4. Means to receive and discriminate signals on different phases and different magnitudes of alternating carrier current of a certain frequency, comprising dynamome-

ter relays each with one winding energized by the received current and each with another winding energized by local current, a source for said local current, and a bridge through which said source is connected to said windings.

5. Means to receive and discriminate signals on different phases and different magnitudes of alternating carrier current of a certain frequency, comprising dynamometer relays each with one winding energized by the received current and each with another winding energized by local current in phase with a desired component of the received current, one such relay being effectively responsible only to polarity changes and another such relay being effectively responsive only to magnitude changes.

6. In combination, a pair of dynamometer relays, with windings energized with current of one phase, and a pair of dynamometer relays with windings energized with current of phase at 90°, and all with windings energized from an incoming circuit, one relay of each pair being responsive to polarity changes and the other relay of each such pair being responsive to magnitude changes, whereby one relay of each pair responds to polarity changes in the properly related component of the incoming current and not to the component at 90° thereto.

In testimony whereof, I have signed my name to this specification this 18th day of June, 1924.

HARRY NYQUIST.