May 15, 1928.

1,669,449

S. BRAND

MULTIPLEX SIGNALING SYSTEM

Filed May 1, 1926

3 Sheets-Sheet 1

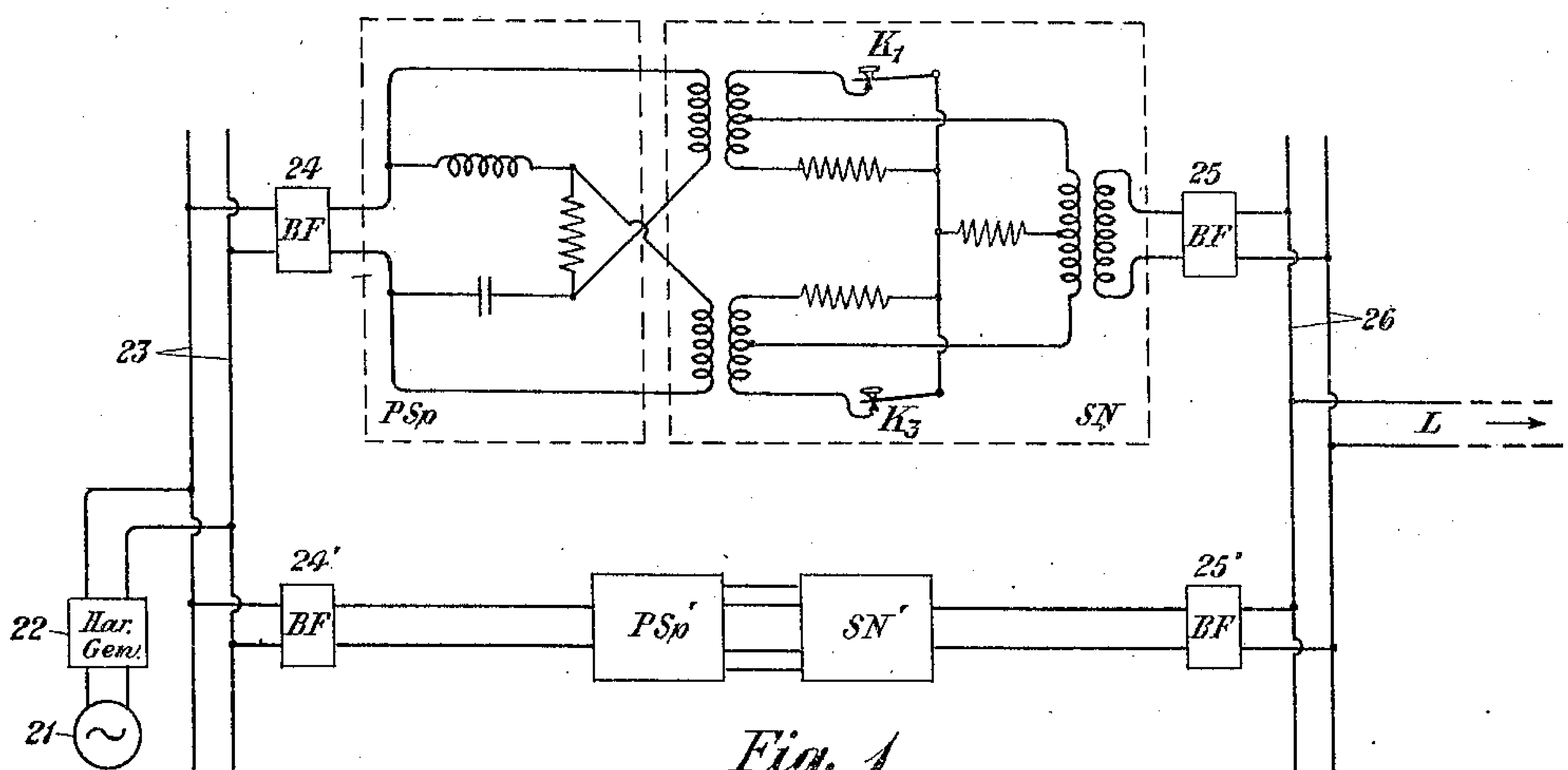

Fig. 1

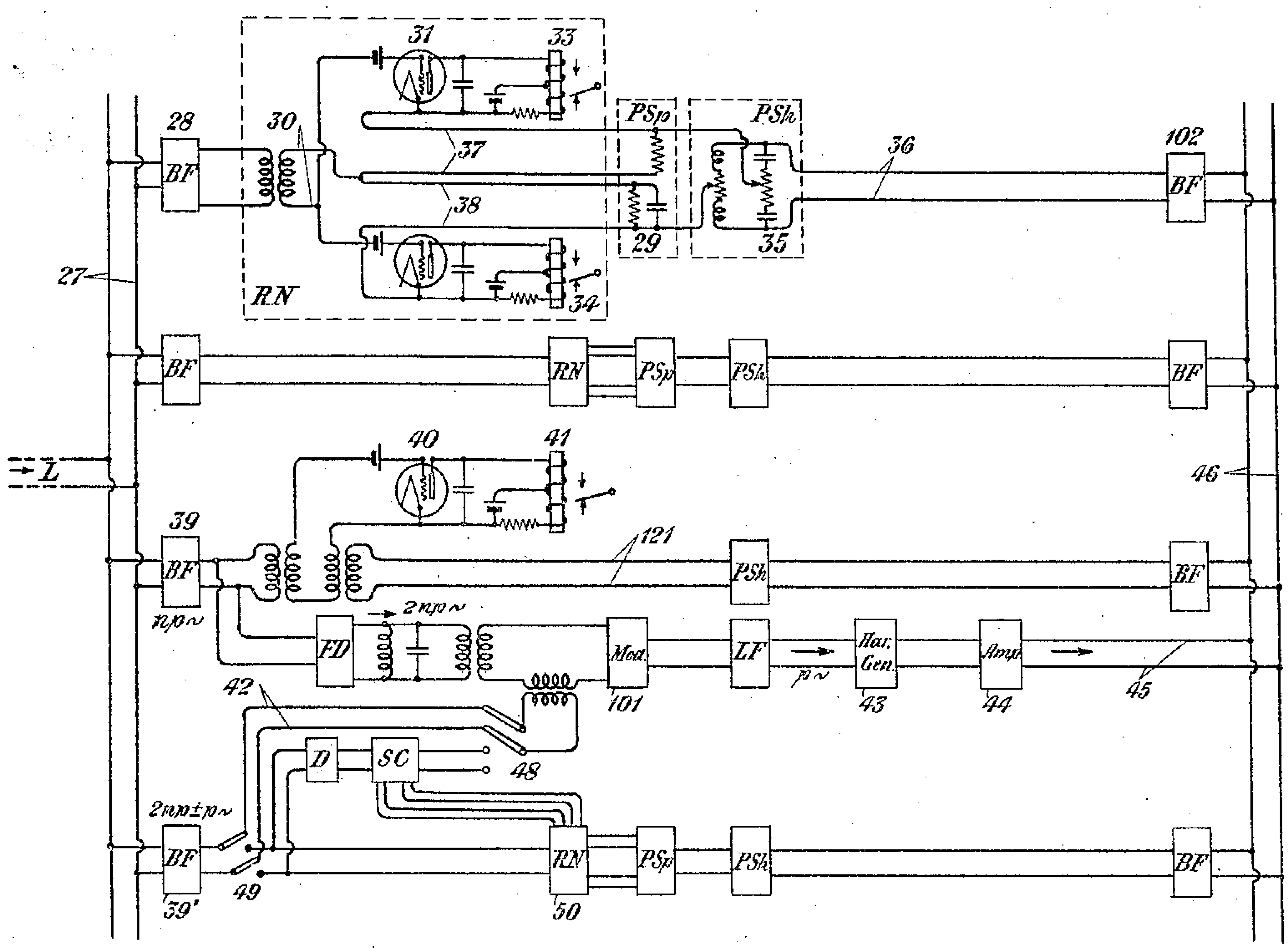

Fig. 2

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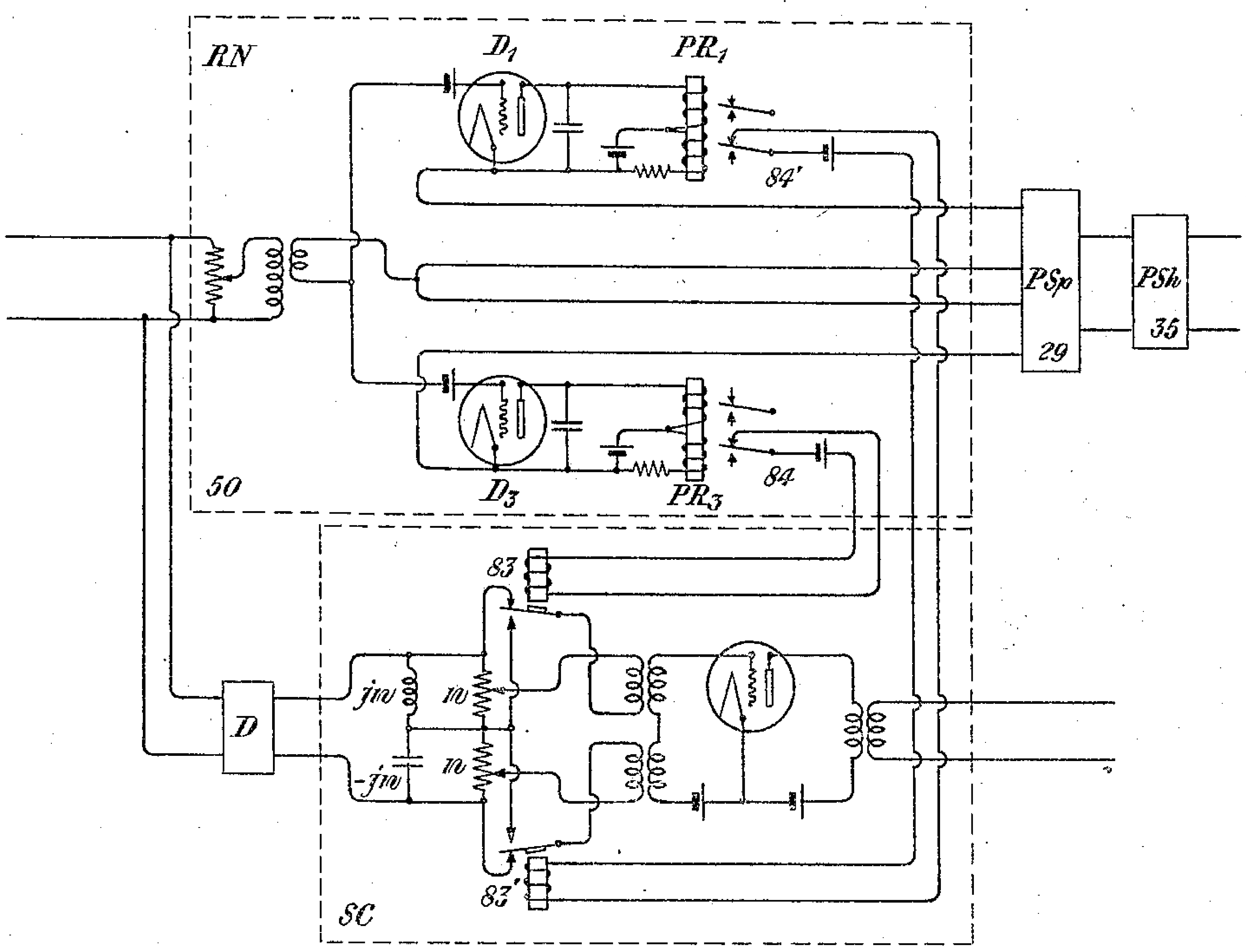

Fig. 3

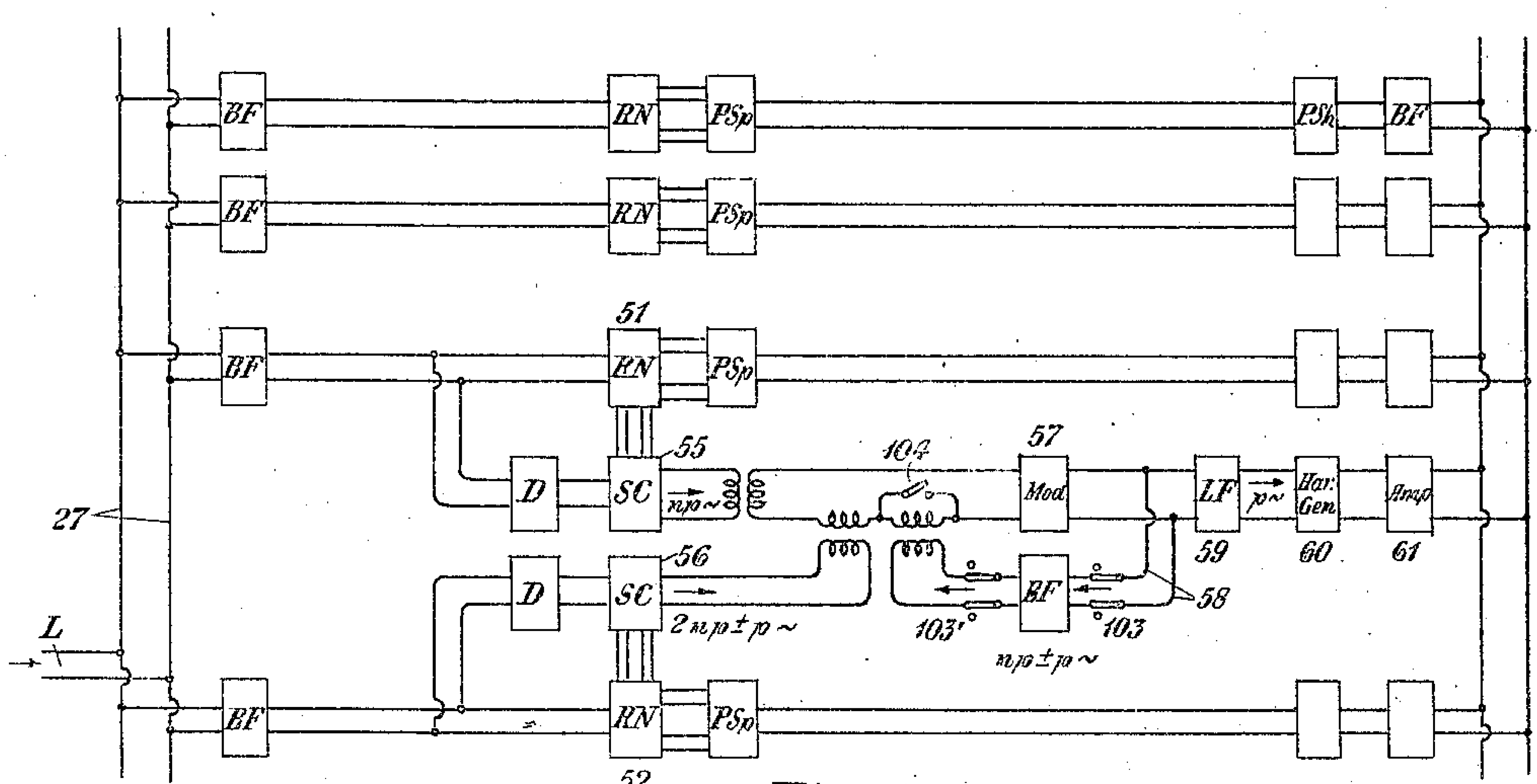

Fig. 4

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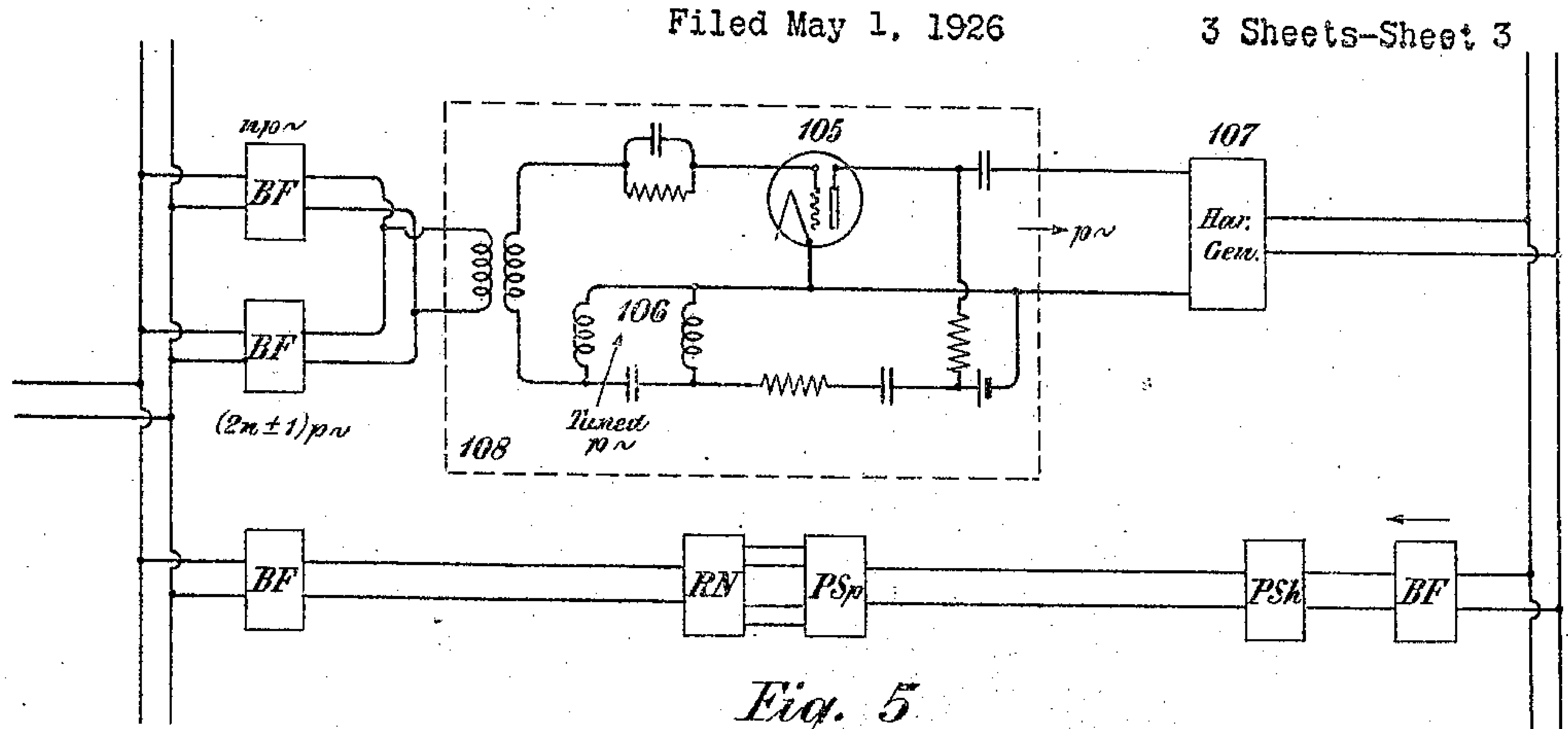

Fig. 5

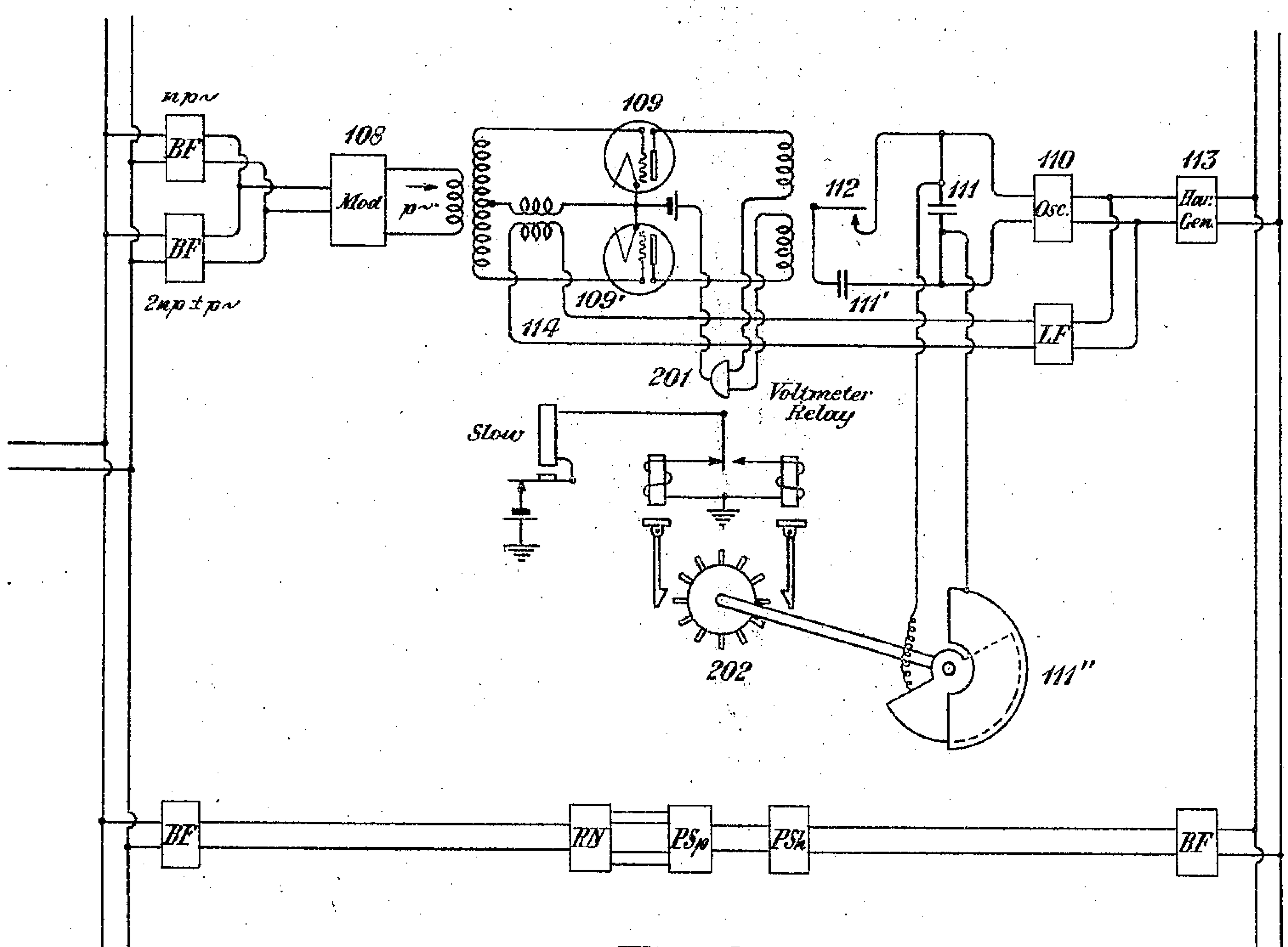

Fig. 6

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UNITED STATES PATENT OFFICE.

SMART BRAND, OF BROOKLYN, NEW YORK, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

MULTIPLEX SIGNALING SYSTEM.

Application filed May 1, 1926. Serial No. 106,100.

It is an object of my invention to provide apparatus and a method for multiplex carrier current signaling. Another object of my invention is to provide a system adapted for receiving by the aid of locally produced currents in proper synchronism and phase relation with the received currents. In a more limited aspect, my invention relates to providing such currents at the receiving end without necessarily transmitting the fundamental of which these currents are harmonics. These objects and various other objects of my invention will become apparent on consideration of a limited number of specific embodiments of the invention which I have chosen to illustrate and describe in this specification by way of example. It will be understood that the following description relates more particularly to these embodiments of the invention, and that the scope of the invention is to be determined from the appended claims.

Referring to the drawings, Figure 1 is a diagram of transmitting apparatus adapted for sending two phase-distinguished messages on each frequency of a multiplex carrier current system. Fig. 2 is a diagram showing corresponding receiving apparatus. Fig. 3 is a diagram giving details of the receiving network and signal compensator shown symbolically in Fig. 2. Figs. 4, 5 and 6 are diagrams of respective alternative receiving apparatus.

Referring to the transmitting apparatus shown in Fig. 1, the oscillator 21 generates an alternating current of fundamental frequency which is deliverd to the harmonic generator 22 whose output may be made conveniently to comprise various odd harmonics of the said fundamental. This composite output current is put on the conductors 23, and the various harmonics are passed respectively by the band filters 24 in multiple.

The current of single harmonic frequency from each band filter 24 goes to a respective phase splitter PSp from which two output currents of the same frequency but 90° apart in phase are transmitted and superposed in the input of a band filter 25. Each of these two current components is controlled for signaling by a respective key K_1 or K_3. The operation of such a key reverses the phase of the current component controlled thereby. The two currents of the same frequency, 90° apart in phase, and each reversed in phase from time to time by a change from marking to spacing or from spacing to marking by its respective key, are superposed and passed through the band filter 25 and put on the conductors 26 and thence to the line L.

Other harmonic components are sifted from the conductors 23 by respective band filters 24′ and put through phase splitters PSp' and sending network SN′ like those already described. The output currents from such sending neworks are put through respective band filters 25′ and superposed on the line L.

At the receiving station shown in Fig. 2, the currents go from the line L to conductors 27 and thence to respective band filters such as 28 and 39 in multiple. These band filters pass the respective harmonic frequencies corresponding to the band filters 24 and 25 at the sending end. One of these harmonic frequency currents is passed by the band filter 28. Through the conductor pair 30 the output currents from this filter have their electromotive forces applied alike to the grids of the two detectors 31 and 32.

By means presently to be described, a current is generated locally of the same frequency as that passed by the band filter 28, and this local current is supplied over the conductor pair 36 to the adjustable phase shifter 35 and thence to the phase splitter 29. From the phase splitter 29 two component currents, 90° apart in phase, go over the conductor pairs 37 and 38, and are applied respectively across the grids and filaments of the detectors 31 and 32.

Of the two 90° components received over the line, both will be applied to the grid of the detector 31, but one of them will be in phase (or in phase opposition) with the locally supplied current over the conductors 37, and the other 90° component will be in quadrature. This statement is based on the assumption that the phase shifter 35 is given a proper adjustment. Only the first component will be effective in the detector output circuit, and the polar relay 33 will accordingly indicate the phase reversals on this one component as determined by the corresponding key K_1 at the sending end. Similarly, the message signals on the other 90° component will be indicated by the relay 34 associated with the remaining detector 32.

At the sending end, one of the sending networks such as SN or SN′ has its two keys locked against manipulation so that for the corresponding harmonic component of current there are no phase reversals. This component of current is received through the band filter 39′ and passed over the conductors 42 to the input side of the modulator 101. In another of the sending networks at the sending station, one of the two 90° components is prevented from reaching the line so that through this sending network a current of the corresponding frequency controlled by a single key is put on the line. This current is received through the band filter 39. On this message channel the signaling is done by phase reversals. The output current from the band filter 39 goes to the detector 40 and is indicated by the receiving relay 41. Locally generated current from a source presently to be described and of the same frequency is supplied over the conductors 121 to co-operate in the reception by means of the detector 40 and the relay 41.

Bridged across the output from the filter 39 is a frequency doubler FD whose output current is accordingly of frequency $2np$, the input being of frequency np. The current passed by the band filter 39′ is of frequency $2np \pm p$ cycles per second. It will be seen that the current components to the band filters 39 and 39′ are odd harmonics of the fundmental frequency p, but by virtue of the frequency doubler FD, the two superposed input currents to the modulator 101 have the respective frequencies $2np$ and $2np \pm p$. Accordingly, the modulator output current will comprise, among its components, a current of the fundamental frequency p, and the low pass filter LF will pass only this fundamental current. This goes to the harmonic generator 43 whose output goes through the amplifier 44 and the conductors 45 to the bus-bars 46, from which the various band filters such as 102 take off the respective harmonic frequencies and put them through respective adjustable phase shifters like 35 and apply them to the phase splitters PSp and receiving networks RN. Thus it is that the locally generated currents are received over the conductors 36 and 121, as stated above.

The two received currents selected for deriving the fundamental have the frequencies np and $2np \pm p$. In any case, they should be chosen so that their greatest common divisor will be p. I refer to two such frequencies as having a prime harmonic relation.

It will be seen that in the system as above described there are normally two message channels on each frequency channel, but three message channels are appropriated to afford frequency channels for deriving the fundamental. By this appropriation of channels for deriving the fundamental, we eliminate synchronizing apparatus that might otherwise be necessary and we also get the local auxiliary current in correct phase relation which might not be easy to do for the fundamental if synchronization were attempted by means of a harmonic.

By throwing switches 48 and 49 in Fig. 2, and putting the received currents through the delay network D and the signal compensator SC on their way to the modulator 101, it becomes possible to transmit and receive signals on the harmonic components of frequency $2np \pm p$. Such signals will be transmitted by the keys that were locked up before. The details of the signal compensator SC are shown in Fig. 3. As will be explained presently, it is so controlled from the receiving network 50 that compensation is effected for the signal changes, and the output from the signal compensator SC is a pure alternating current unaffected by signaling changes. When the switches 48 and 49 are thrown, as suggested above, it will be seen that only one message channel is appropriated for deriving the fundamental in the system of Fig. 2.

Referirng to Fig. 3, the receiving network RN or 50 has the two receiving relays PR_1 and PR_3, and each control an additional pair of contacts at 84′ and 84. These contacts control circuits to the signal compensator SC.

The same received currents that go in part to the receiving network 50 or RN also go in part in multiple through the delay network D to the signal compensator SC. The relays 83 and 83′ within the signal compensator SC control the network therein so as to compensate for the effect of the signal changes, and the delay network D gives time for these changes to be made at the proper stage. Accordingly, the output from the compensator SC will be a simple alternating current unaffected by signaling changes, as stated above in connection with Fig. 2.

A modified receiving system is shown in Fig. 4. The received carrier currents of frequency np go to the receiving network 51 in the usual way. Bridged across the input to this receiving network is a delay circuit D with output connected to the signal compensator 55. As explained heretofore, the output from this signal compensator will be a pure current of frequency np unaffected by signal modifications. This current goes to the modulator 57.

Similarly, currents of frequency $2np \pm p$ are delivered from the signal compensator 56 to the same modulator 57. One of the modulation output currents produced is a current of frequency $np \pm p$, which is fed back through the conductors 58 and the band filter BF to the input of the modulator 57.

Accordingly, the output from this modulator 57 will also comprise a component current of frequency p which is passed by the low pass filter 59 to the harmonic generator 60. The output from this harmonic generator comprises all the harmonics of the fundamental frequency p, as at the sending end. These are amplified by the amplifier 61 and distributed to the various phase splitters and receiving networks in the manner heretofore described.

The modulator 57 may be so designed and arranged that third order terms will be present in its output. In this case, the switches 103 and 103′ may be opened, and 104 closed; thus there will be no feed-back, but the current of frequency p will be found amoung the modulation output components and will be sifted through the low pass filter 59, and the rest of the operation will be as described with the switches in the positions shown in Fig. 4.

Another modification is shown in Fig. 5. In this case, the two received carrier current components of frequencies np and $2np \pm p$ are sifted out from the received current by respective band filters and superposed on the input of the oscillating audion 105. The associated tuned circuit 106 is tuned as nearly as practicable to the frequency p as determined at the sending end, so that the audion 105 naturally oscillates approximately at this frequency.

The adjustment of the tuned circuit 106 could not be made accurately enough to keep the oscillator 105 in precise synchronism and phase relation with the fundamental current of frequency p at the sending end. When an oscillator is tuned approximately to a certain frequency, then if a current of that frequency or a simple harmonic thereof is superposed in its input, it will hold the oscillator exactly in step at the intended frequency. If there is only one harmonic current applied in the input, it will give assurance that the frequency of the oscillator will be held at the same frequency as the fundamental of the said harmonic, but different phase relations between the oscillator output frequency and the said fundamental will be possible.

By applying two different harmonic components such as np and $2np \pm p$ to the input of the oscillator of approximate natural frequency p, it is forced by both of them and is not only synchronized to the fundamental in respect to frequency, but also is brought into a unique phase relation with the fundamental corresponding to the said two harmonics. Hence, the output current of frequency p from the oscillator 105 is in proper phase relation with the fundamental current of frequency p at the sending end, and whenever the system is started up after a suspension of operation, this output current of frequency p will be generated in proper phase. It is put through the harmonic generator 107 and its output harmonic components are supplied to respective phase splitters and receiving net-works for the system, as described for Figs. 2 and 4.

Another modification is shown in Fig. 6. Here, as in Fig. 5, the two received currents of frequencies np and $2np \pm p$ are filtered and superposed in the modulator 108 corresponding to the dotted line box 108 of Fig. 5. The output current of frequency p from the modulator 108 of Fig. 6 is applied oppositely to the grids of the detectors 109 and 109′.

The oscillator 110 has the condenser of its oscillating circuit at 111, and another condenser 111′ is provided which may be connected in parallel with 111 by the closure of the switch 112. With the switch open, the oscillator 110 is tuned slightly above the frequency p, but with the switch 112 closed, the tuning is slightly below the frequency p. The output from the oscillator 110 goes to the harmonic generator 113, and the harmonics are distributed thence to the phase splitters and receiving networks, as heretofore described.

Bridged across the output from the oscillator 110 is a filter LF that passes the current of frequency p over conductor 114 and superposes the corresponding electromotive force alike on the grids of the detectors 109 and 109′. When these two inputs via 108 and 114 are in quadrature, the detector output circuit relay will hold its armature 112 at neutral, but when the input at 114 gets a little ahead of the 90° relation with the input from 108, the armature at 112 will close and slow down the oscillator 110 until the quadrature relation is restored, when it will open again. Thus it will be seen that the arrangement of Fig. 6 provides a local oscillator 110 of approximately the fundamental frequency p which is held closely to that frequency by a current of exactly that frequency derived from two harmonics thereof received over the line.

The voltmeter relay 201 operates when the departure from the quadrature relation becomes excessive. As shown in Fig. 6 it produces a comparatively slow stepped motion of wheel 202 so as to adjust condenser 111″ which is in parallel with 111. By the voltmeter relay 201, the capacity of the combined condensers 111 and 111″ is kept close to its proper value, and then by means of condenser 111′ and switch 112 a supplemetal fine adjustment is made.

I claim:

1. In multiplex carrier current signaling with the generation of currents of the carrier frequencies at the receiving end, the method which consists in modulating together two received carrier currents, and

from the modulation product, filtering out a current of fundamental frequency of which the carrier frequncies are harmonics, and determining thereby the frequencies and phase relations of the currents generated at the receiving end.

2. In multiplex carrier current signaling with the generation of currents of respective carrier frequencies at the receiving end, the method of securing definite synchronism and phase relation between each received current and the respective current generated at the receiving end, which consists in selecting two of the received currents having a prime harmonic relation to each other and applying them both to effect synchronism whereby all the currents are synchronized respectively at definite phase relations.

3. The method of controlling the generation of one alternating current by another, which consists in applying two different selected harmonics of the one current to force the generation of the other current in definite synchronism and phase relation.

4. The method of controlling the generation of a set of currents all harmonics of a certain fundamental, which consists in applying two different selected harmonics of another corresponding set to hold them all in respective synchronism and definite phase relation.

5. The method of synchonizing the output of a vacuum tube oscillator with a given alternating current, which consists in superposing in the oscillator input two different selected harmonics of the said given current.

6. In a multiplex carrier current signaling system, means at the receiving end to generate locally a set of currents corresponding respectively in frequency with the received component carrier currents and means to apply two of the said received carrier currents to synchronize said first mentioned means whereby the entire set of locally generated currents will be definitely synchronized with the corresponding received currents respectively.

7. In combination, an alternating current generator, means to produce harmonic currents, a vacuum tube oscillator and means to superpose two of the said harmonic currents in the input of said oscillator to force it to operate at the frequency of the said generator.

8. In combination, two alternating current generators of approximately the same natural frequency, and means to hold them in definite synchronism and phase relation by the application of two selected harmonics of the current from one generator applied to control the other generator.

9. In combination, an alternating current generator, means to produce harmonic currents, a second generator, and means for impressing on the second generator two selected harmonics of the current of the first generator to cause it to yield as its fundamental the difference of the frequencies of the two selected harmonics.

In testimony whereof, I have signed my name to this specification this 29th day of April, 1926.

SMART BRAND.