

Dec. 15, 1931.

E. I. GREEN

1,836,114

SYSTEM OF CARRIER CURRENT SIGNALING ON POWER LINES

Filed Feb. 25, 1928 2 Sheets-Sheet 1

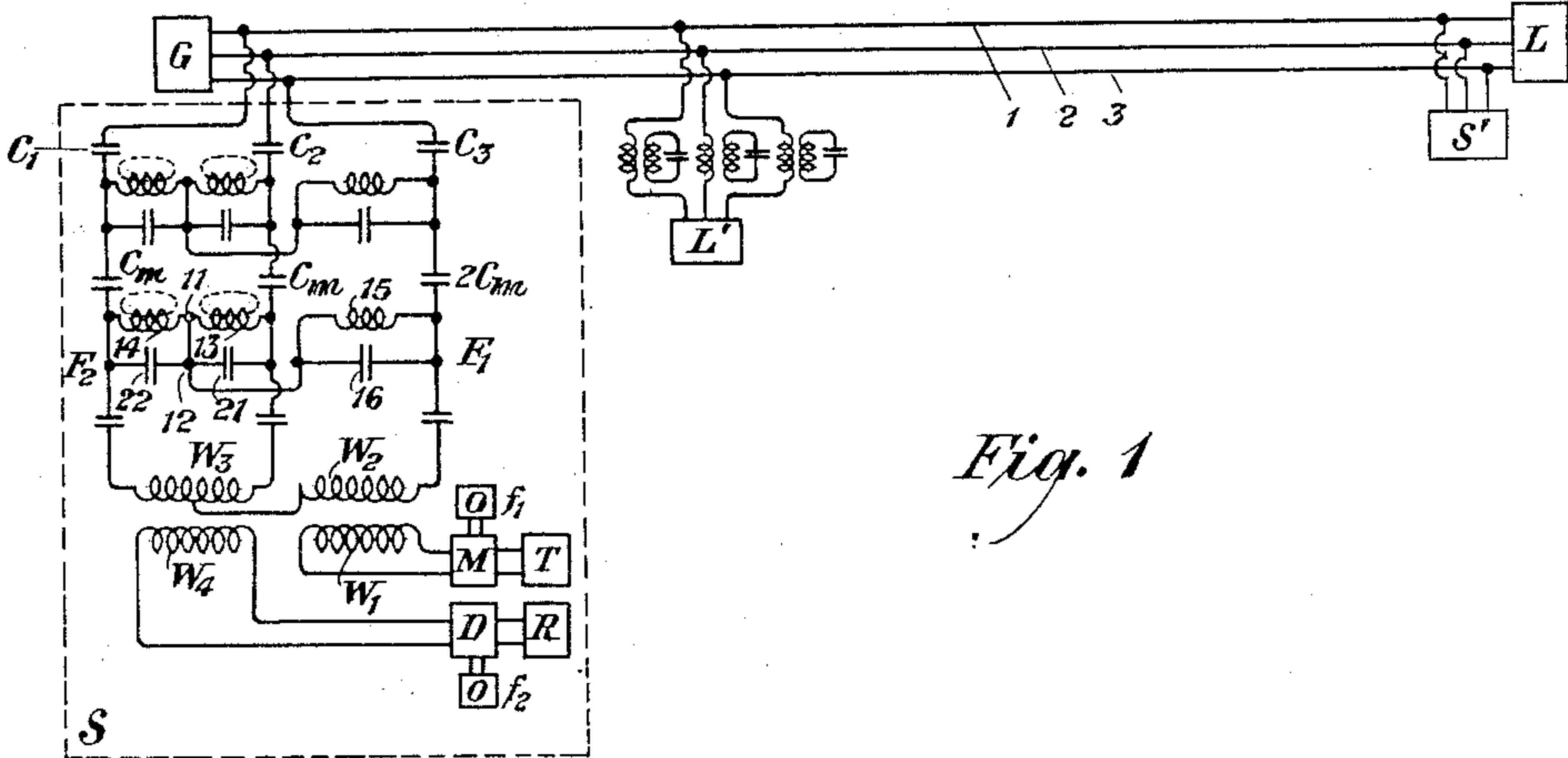


Fig. 1

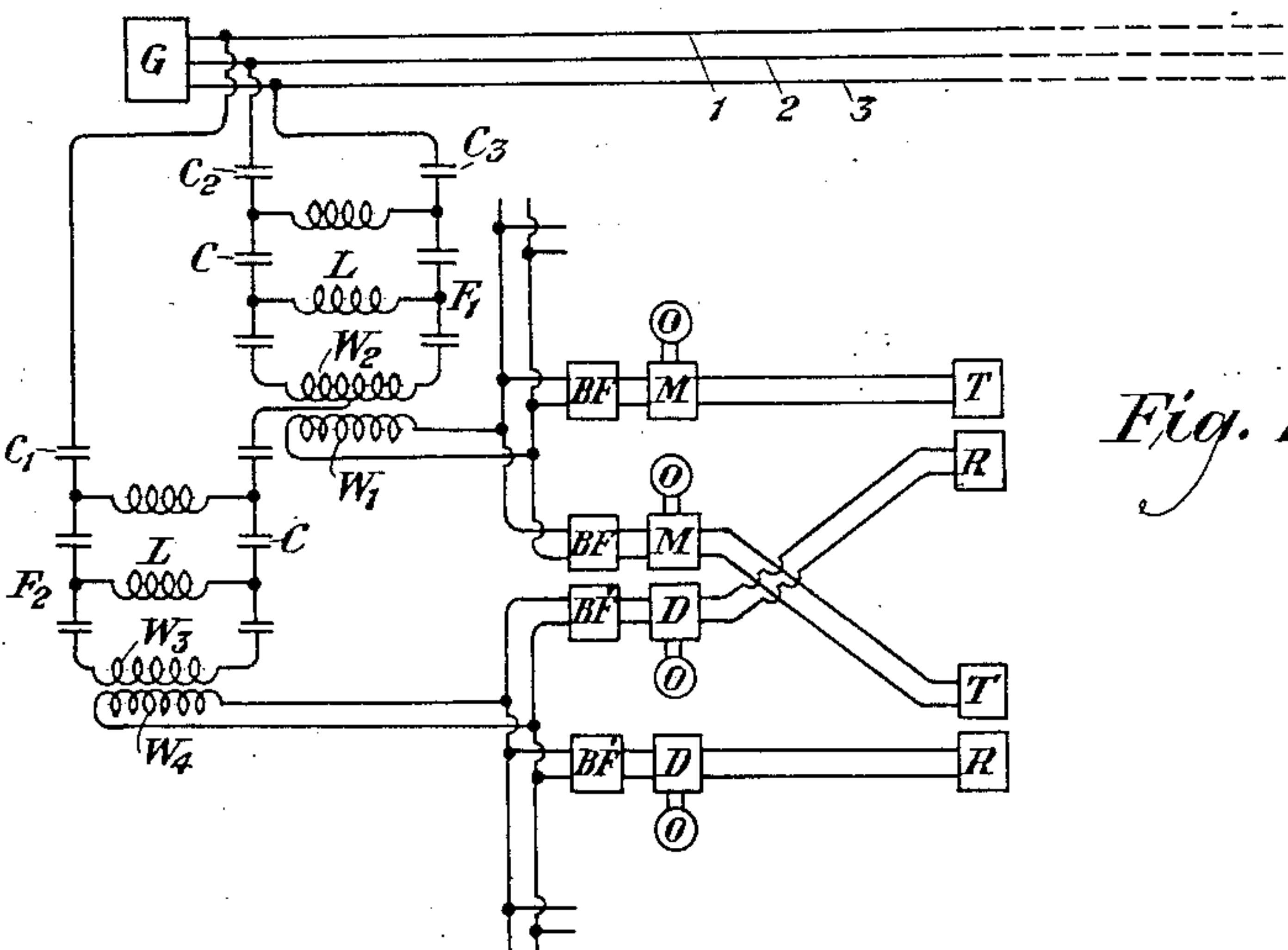


Fig. 2

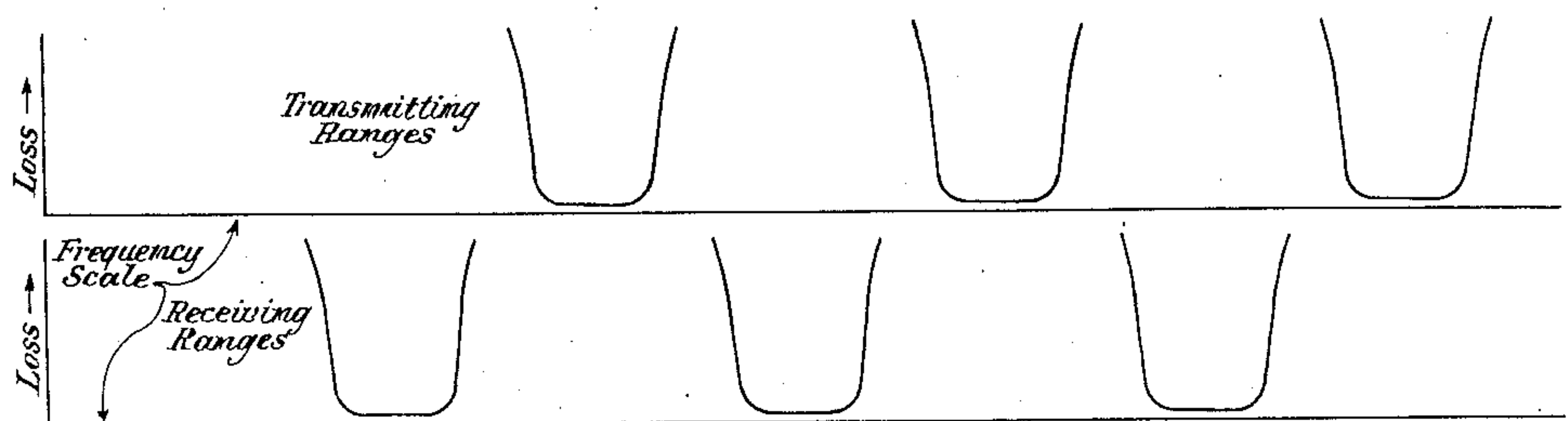


Fig. 3

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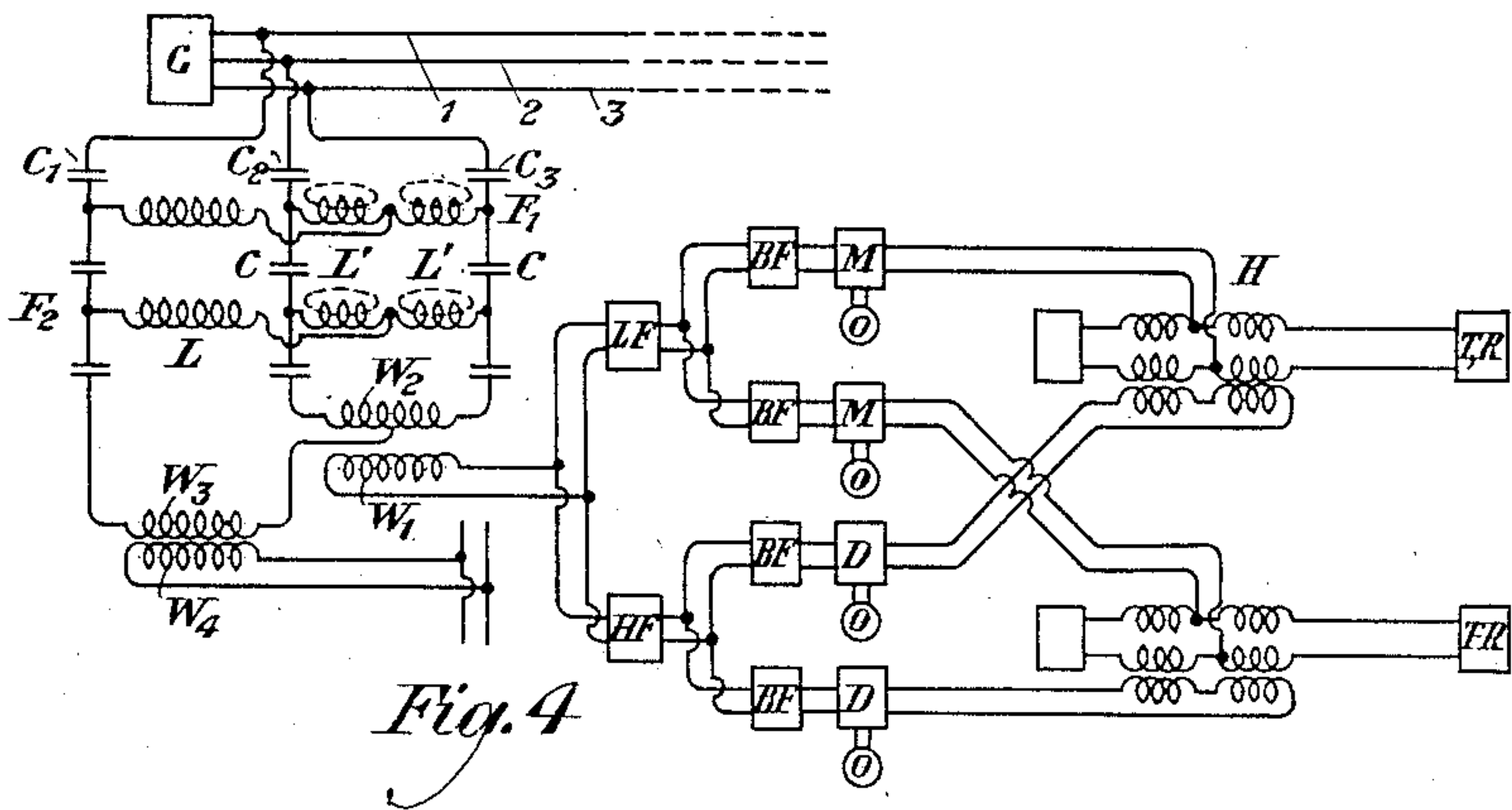


Fig. 4

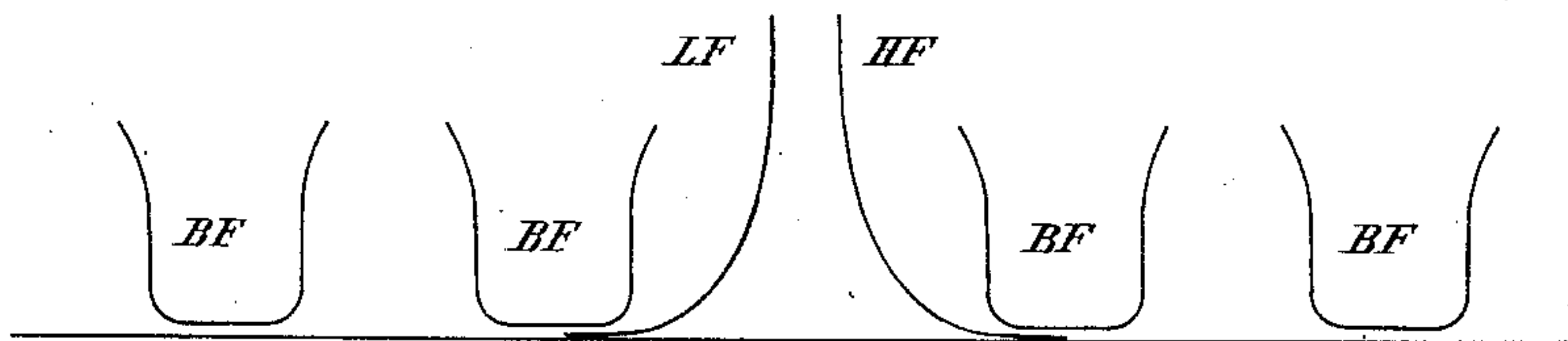


Fig. 5

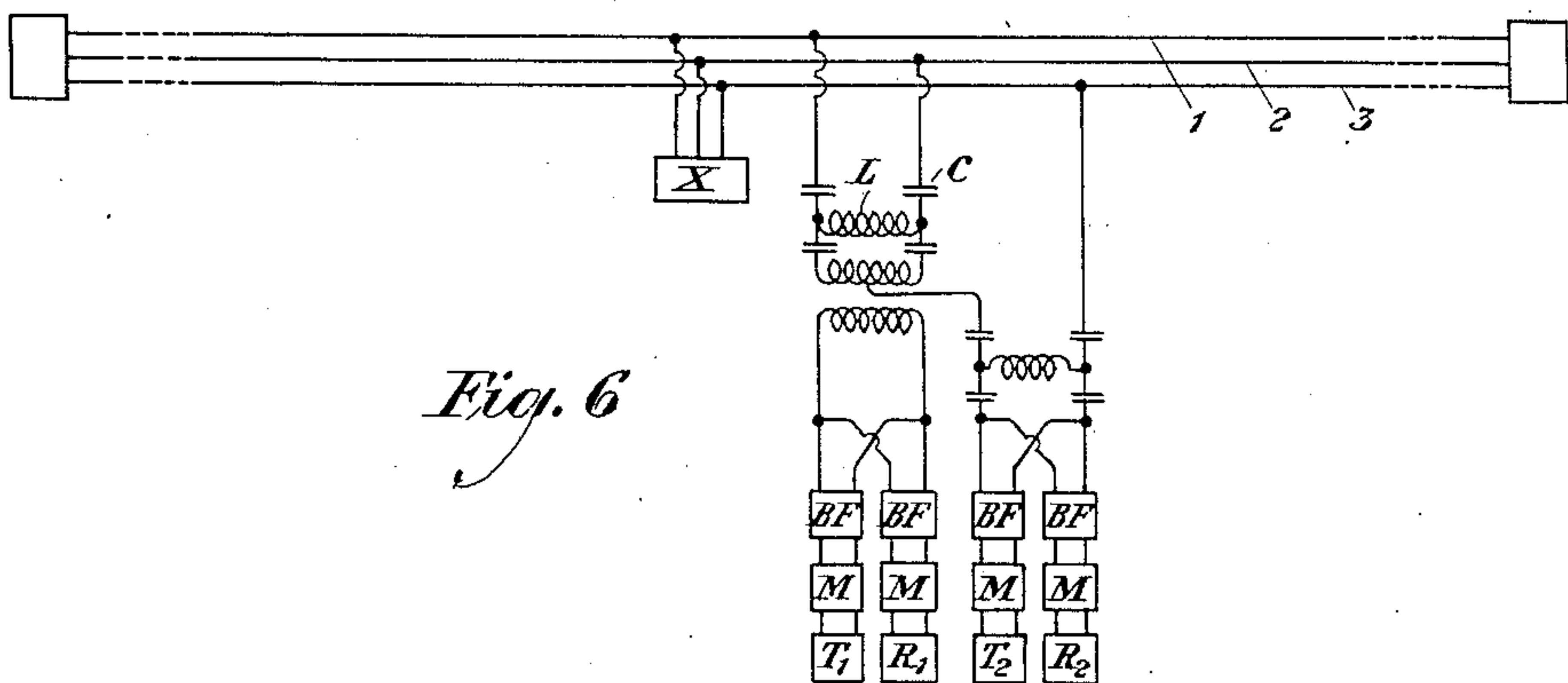


Fig. 6



Fig. 7

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SYSTEM OF CARRIER CURRENT SIGNALING ON POWER LINES

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Among the objects of my invention are to provide a new and improved method and corresponding apparatus for multi-channel carrier current signaling on multi-phase power lines. Another object of my invention is to utilize capacity coupling between carrier signaling apparatus and power conductors for the derivation of two metallic carrier signaling paths from a power line of three conductors. Another object of my invention is to provide for the operation of two signaling circuits on the conductors of a three-phase power transmission line without the use of a ground return. Other objects of my invention have relation to producing an approximate balance between two such signaling paths and selectively confining the different currents in the proper channels of a multi-channel carrier system. These and other objects of my invention will become apparent on consideration of a limited number of examples of practice according to the invention, which I have chosen for disclosure in the following specification. It will be understood that this specification relates principally to these particular examples of practice according to the invention and that the scope of the invention will be indicated in the appended claims.

Referring to the drawings, Figure 1 is a symbolic diagram of a power transmission system with a superposed two-way carrier current telephone system embodying my invention; Fig. 2 is a diagram showing a three-phase power transmission system with a superposed multiplex carrier current signaling system; Fig. 3 is an attenuation-frequency diagram for certain filters of Fig. 2; Fig. 4 is a diagram of a system like that of Fig. 2, but modified in certain respects; Fig. 5 is an attenuation-frequency diagram for certain filters of Fig. 4; Fig. 6 is a diagram for a system of independent carrier current communication two ways from an intermediate location on a power network; and Fig. 7 is a frequency diagram for the filters of Fig. 6.

A three-phase power transmission system is shown symbolically in Fig. 1 with the generating station G connected by the three

conductors 1, 2 and 3 to the distant load L. The conductors 1, 2 and 3 may also be tapped at intermediate points to supply current to other loads such as L'.

Two-way telephone stations are represented at S and S', each with a transmitter T and a receiver R. The circuit from the transmitter T goes to the modulator M, where the voice currents modulate carrier current of frequency f_1 generated by the generator O, and the modulated carrier currents of basic frequency f_1 go to the winding W_1 of the transformer W_1-W_2 .

Each of the three condensers C_1 , C_2 and C_3 has one plate connected with a respective power conductor 1, 2, or 3. Connected with the remaining plates of the two condensers C_1 and C_2 is a band-pass filter F_2 whose other end is connected to the terminals of the transformer winding W_3 . This band-pass filter F_2 has its elements in balanced relation with respect to the two terminals at either end, that is, for the series elements there are equal condensers such as C_m on each side and for the shunt elements there are coils and condensers in parallel but arranged so that each is accessible for a tap at its midpoint, as shown at 11 and 12. Each of the coils 13 and 14 has an independent core and an independent magnetic circuit, as indicated by the closed dotted lines in the figure.

The filter that has just been described is connected at its output end through the transformer windings W_3 and W_4 to the demodulator D which is supplied with current of frequency f_2 from the generator O. The output from the demodulator D goes to the telephone receiver R.

There is another band-pass filter F_1 whose input terminals are connected with the transformer winding W_2 . Its series members on one side are condensers such as the one labeled $2C_m$ and on the other side the two condensers marked C_m in parallel, and its shunt members are the coil and condenser combinations comprising coil 15 and condenser 16 in parallel, and these in series with the two coils 13 and 14 and the two condensers 21 and 22, these four elements in parallel. It will be seen that on one side the shunt combinations,

such as 15, 16 are connected between the series condensers such as $2C_m$, and on the other side they are connected to the middle points of the shunt elements of the first described filter.

Accordingly, the filter F_1 is connected to the power line so as to utilize its conductors in a "half phantom" arrangement, that is, with the conductor 3 for one side of the circuit, and the conductors 1 and 2 in parallel for the other side of the circuit.

The band-pass filter F_1 passes a range of frequencies corresponding to one or both of the sidebands of the frequency f_1 . Accordingly, the modulated carrier current carrying the voice waves from the transmitter T and having the basic frequency f_1 goes through this filter F_1 and is transmitted from left to right over the circuit consisting of the power conductor 3 on one side and the power conductors 1 and 2 in parallel on the other side.

On the other hand, at station S' modulated carrier currents of basic frequency f_2 are put on the line and the filter F_2 at station S passes a range of frequencies corresponding to one or both of the sidebands of the frequency f_2 . From the filter F_2 these received modulated carrier currents go through to the demodulator D which reduces them to normal voice currents for delivery to the receiver R.

While the fundamental frequency for the power transmission system will be low compared to the carrier frequencies f_1 and f_2 , these power currents are likely to have harmonics present, and such harmonics will be excluded from the station S by the filters F_1 and F_2 , except if they happen to lie in the frequency ranges passed by those filters. If the power lines were well balanced, having very low crosstalk between the circuit formed by conductors 1 and 2, and the circuit formed by conductor 3 and conductors 1 and 2 in parallel, then the balancing arrangements at station S in the transformers W_1-W_2 and W_3-W_4 would serve to keep the currents distinct in the transmitting and receiving channels. But in some cases such a high degree of line balance cannot be expected for a three-phase power transmission system, and accordingly, an important function of the filters F_1 and F_2 is to aid in keeping the currents distinct and separate in the transmitting and receiving channels. This is accomplished in high degree by transmitting on a carrier current of one frequency f_1 and receiving on another carrier current of a different frequency f_2 and building the filters to pass the corresponding frequency ranges, respectively. It should be noted, however, that the line balance, even though insufficient to permit operating in both directions with the same frequency band, nevertheless makes it possible to bring the transmitted and received bands much closer together than would be possible if the transmitted and received currents were transmitted over the same line circuit.

The anti-resonant loops in the branch conductors to load L' are tuned broadly to the mean frequency $(f_1 + f_2)/2$, and prevent any considerable diversion of the signaling currents to the power conductors leading to the load L' .

By my invention, as embodied in the system of Fig. 1, it will be seen that I connect the carrier terminal apparatus to the power line through condensers such as C_1 , C_2 and C_3 , and that I get two distinct circuits for the carrier currents without employing grounds, and utilizing only the three conductors of the three-phase system. The use of some form of capacity coupling is very desirable for effecting a connection between carrier apparatus and power conductors. In the practice of my invention various forms of capacity coupling may be employed. Thus the condensers C_1 , C_2 , and C_3 may be standard condensers designed to withstand the power line voltages, they may be sections of high-voltage oil-filled power cable, or they may be formed by coupling antennae mounted in proximity to the power conductors.

Although the condensers C_1 , C_2 , and C_3 have been shown as forming elements of two band filters, they may be used as parts of tuned circuits for selecting the desired frequencies.

In the modification shown in Figs. 2 and 3, the filters F_1 and F_2 are high pass filters with their critical or cut-off frequencies so determined that they pass the carrier currents but do not pass the comparatively low frequency power currents nor their lower order harmonics. This system is adapted for multiplex telephone transmission, two terminal stations being shown each equipped with a transmitter T and a receiver R. The different transmitting channels are separated and determined by the band filters BF with respective ranges as indicated in the upper part of Fig. 3. The different frequency ranges for the different transmitters are superposed in the winding W_1 of the repeating coil W_1-W_2 and put through the high pass filter F_1 and through the condensers C_1 and C_2 to the circuit formed by the two conductors 2 and 3 of the three-phase power line.

It will be seen that for the repeating coil W_3-W_4 its primary winding W_3 is connected across the power conductor 1 and the power conductors 2 and 3 in parallel. I refer to this connection as "half-phantom". Signal carrier currents incoming on this half-phantom circuit go through the condensers C_1 on one side and C_2 , C_3 in parallel on the other side, and through the high pass filter F_2 and the repeating coil W_3-W_4 and thence in multiple to the band filters BF' , which have their pass ranges spaced apart and staggered in relation to the transmitting ranges as indi-

cated in the lower part of Fig. 3 compared with its upper part.

It will be seen that in the system of Fig. 2 a plurality of two-way talking circuits is provided and that in all of them transmission is on the two-conductor circuit of the power system and reception is on the half-phantom circuit of the power system. Of course, this system will be reversed for the station at the opposite end of the line where the transmitted currents will be those received at the end pictured in Fig. 2 and the received currents will be those transmitted at the end pictured in Fig. 2.

In the system shown in Fig. 2, the balance is partly depended on to keep the transmitted currents out of the receivers at the same end, and also this object is gained by the band pass filters BF and BF' with their different ranges. Unlike Fig. 1, the filters F_1 and F_2 of Fig. 2 do not separate the transmitted and received currents.

The use of the line balance as an aid in preventing the entrance of the transmitted currents into the receiving circuits permits the location of the transmitting bands much closer in frequency to the receiving bands than would be possible if both transmitting and receiving currents utilized the same line circuit. This results in a large increase in the number of carrier channels that may be provided. Obviously if the line cross-talk is sufficiently low, the transmitting and receiving bands may be made to coincide.

Referring to Fig. 4, this shows two high pass filters F_1 and F_2 with the same critical or cut-off frequencies determined as in the case of the high pass filters of Fig. 2. However, the two filters of Fig. 2 are physically distinct from each other, whereas in Fig. 4 certain reactances are common to both filters. Here the condensers C of filter F_1 are utilized in pairs as the condensers on one side for the filter F_2 ; also, the coils of the filter F_1 are made in pairs and each pair connected in multiple with a corresponding coil of the filter F_2 , so that each shunt inductance of the filter F_2 consists of a series coil such as L and the two multiple coils such as L'. In Fig. 2 the filter elements are distinct, whereas in Fig. 4 the elements of the filter F_1 serve not only for that filter but as part of the filter F_2 .

Another distinction between Fig. 4 and Fig. 2 is that instead of staggering the transmitting and receiving ranges as in Fig. 3, these ranges are disposed as shown in Fig. 5. All transmitting through repeating coil W_1-W_2 is through the low pass filter LF and all receiving through the same coil is through high pass filter HF. If the power lines are well balanced, a similar carrier system can be connected through the repeating coil W_3-W_4 . In case the line balance is not good enough to permit the use of identical frequency bands on the two circuits derived from

the three power conductors, then the bands used may be staggered with respect to one another as was done in the system of Fig. 2.

Referring to Fig. 6, this shows a three phase line or network with conductors 1, 2 and 3 and an intermediate station at which there may be a generator feeding the network, or a load drawing energy therefrom, represented in any case as X. Suppose it is desired to maintain a two-way carrier communication channel on the line on one side of X and another independent like channel on the other side of X; this may be accomplished by the arrangement of apparatus shown in Fig. 6 with the frequencies apportioned as in Fig. 7. It will be seen that four frequency bands are involved and that transmission on one side is on the lowest of these, transmission on the opposite side is on the next higher band, reception on the said one side is on the next higher band, and reception on the said opposite side is on the highest band. Also, both transmission and reception on one side are on the circuit whose two conductors are respectively two conductors of the power line, and both transmission and reception on the opposite side are on the half-phantom circuit.

The invention has been described as applied with carrier apparatus used for giving signals or indications or effects at a distance, and more specifically, in connection with the drawings, the invention has been exemplified in relation to telephone communication.

I claim:

1. A three-phase power-transmitting system comprising three coordinate power conductors, a ladder-type filter having a pair of input terminals and a pair of output terminals, one said pair being connected respectively to two of said conductors, and another filter having one of its terminals connected with the remaining conductor of said three conductors and its other terminal of the same pair connected at a neutral point with respect to the sides of the first mentioned filter.

2. A three-phase power-transmitting system comprising three coordinate power conductors, a ladder-type filter having a pair of input terminals and a pair of output terminals, one said pair being connected respectively to two of said conductors, and another filter having one of its terminals connected with the remaining conductor of said three conductors and the remaining side of said last mentioned filter non-adjacent to said terminal being completed through the elements of the said first mentioned filter by a neutral connection with respect to the sides thereof.

3. In combination, a three-phase power-transmitting system comprising three coordinate power conductors, and in association therewith three condensers, respective connections from one side of each condenser to one of the conductors, a ladder-type filter

having a pair of terminals connected with two of the condensers, another ladder-type filter having one terminal connected with the remaining condenser and the other side of
5 said last mentioned filter being connected neutrally with respect to the sides of the first mentioned filter, the said condensers having the proper capacity values to form terminal series reactances of the said filters.

10 In testimony whereof, I have signed my name to this specification this 24th day of February, 1928.

ESTILL I. GREEN.

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