March 14, 1933. E. PETERSON 1,901,408

BILATERAL MODULATOR CIRCUIT

Filed March 21, 1929 2 Sheets-Sheet 1

FIG. 2.

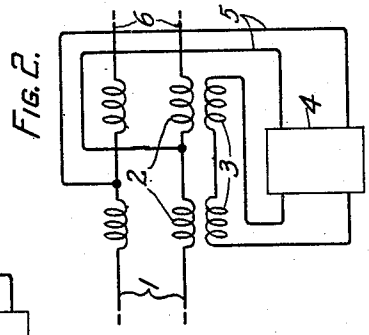
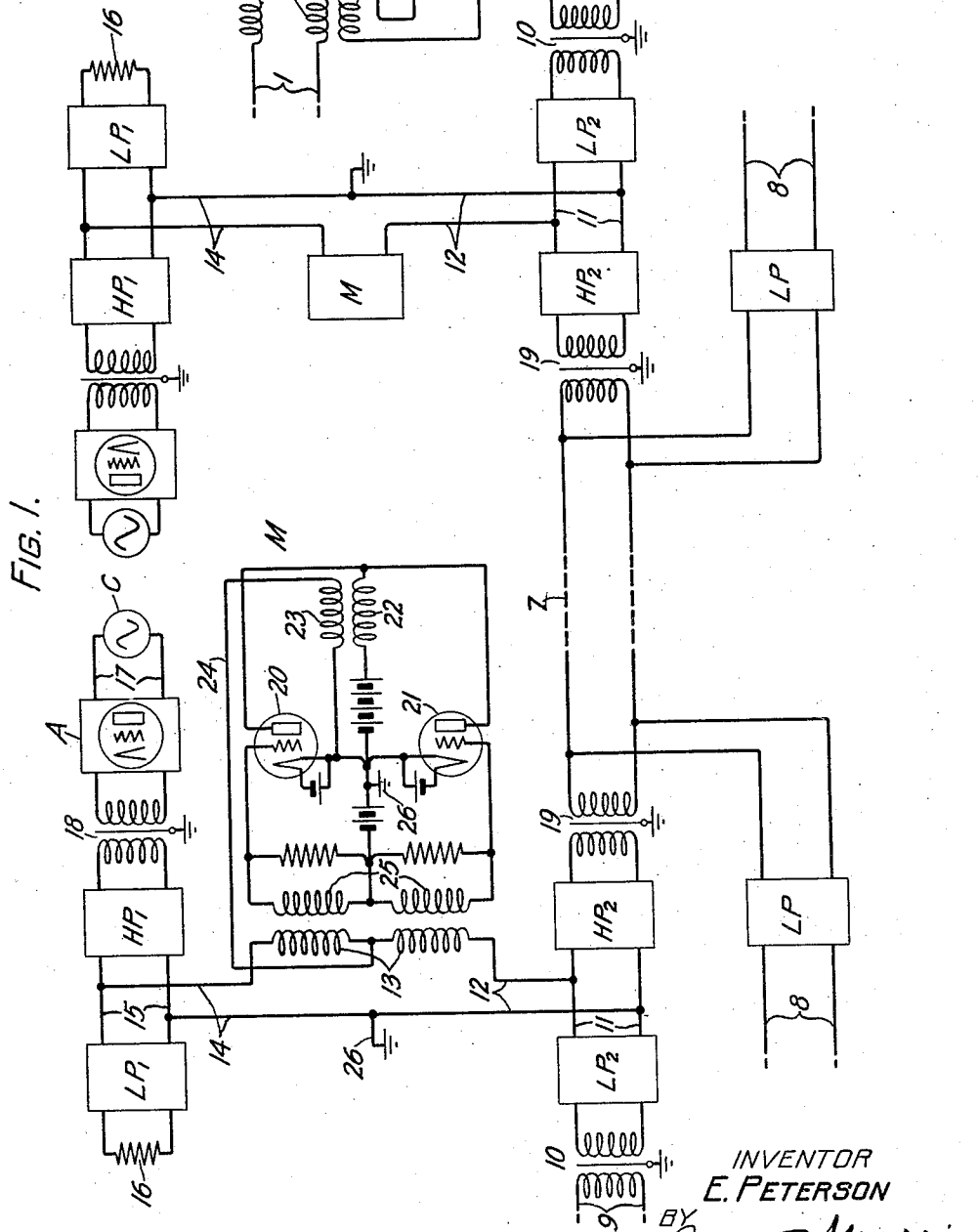


FIG. 1.



INVENTOR
E. PETERSON
BY
Guy T. Morris
ATTORNEY

March 14, 1933. E. PETERSON 1,901,408

BILATERAL MODULATOR CIRCUIT

Filed March 21, 1929 2 Sheets-Sheet 2

FIG. 3.

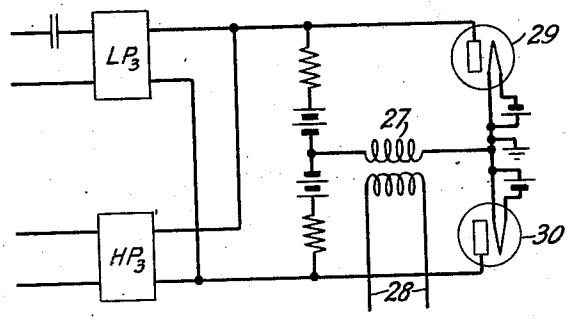
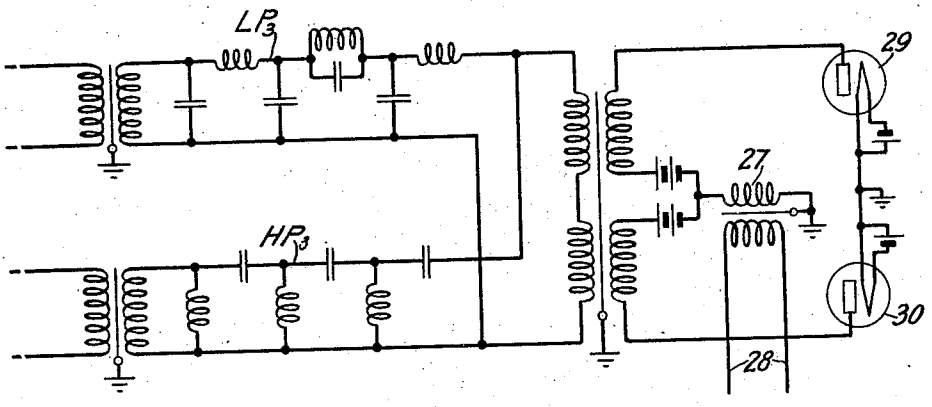


FIG. 4.



INVENTOR
E. PETERSON
BY Guy T. Morris
ATTORNEY

Patented Mar. 14, 1933 1,901,408

UNITED STATES PATENT OFFICE

EUGENE PETERSON, OF NEW YORK, N. Y., ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

BILATERAL MODULATOR CIRCUIT

Application filed March 21, 1929. Serial No. 348,740.

This invention relates to a bilateral modulator circuit, that is, a circuit which employs a common distorting element or modulator for translating a signal wave into corresponding outgoing signal representing carrier side band waves and for conversely translating incoming signal bearing carrier side band waves into the corresponding signal waves.

In order that these two types of frequency translation may be performed in a single device the related circuits from which waves having the respective frequencies are impressed on such device must necessarily be in close physical proximity. In fact, they may more or less completely overlap since certain practical forms of bilateral modulators effectively have only two terminals so that the input and output circuits of the modulator, or from another point of view, the signal and side band impressing circuits, are in part common. The operation of bilateral modulator circuits therefore introduces hazards not found in the more conventional alternative circuit arrangements in which the corresponding circuits are more nearly physically distinct. The component parts of a bilateral circuit tend to react on each other so as to impair their respective functions as well as to promote singing and cause various types of interference.

It is an object of this invention to provide circuit arrangements for bilateral modulator circuits which combine relatively great efficiency, simplicity and low cost with adequate protection against interference and singing, both of which tend to be incidental to the operation of such circuits.

This object as well as other related and incidental objects may be realized in part by the use of frequency discriminating networks. In a particular type of bilateral modulator circuit that is preferred for some purposes, the modulator element is itself unilaterally conducting, so that the modulating currents for outgoing transmission and the incoming side band currents traverse the modulator in the same direction. For this case to provide protection from singing, in addition to the protection afforded as above by frequency discrimination (selection), the principle of balance is used and in particular an arrangement similar in its most fundamental aspect to that used in a repeater circuit which has become well known as the 21-type repeater. Specifically, the modulating and side band currents are caused to traverse in part a common circuit element from which a potential is derived for impressing on the input of such unilateral modulator element. The resultant modulation products, that is, the carrier side band or the reproduced signal as the case may be, are fed back through a reentrant circuit to such element and in such manner as to traverse electrical equivalent portions of it and its associated circuits in opposite directions and therefore by means of one or the other of such portions to its destined terminus where it is to be usefully employed. The relation of the feed back circuit to such element, if an adequate balance is secured, is such that there is no resultant potential impressed from such feed-back circuit on the input of the modulator which if present would tend to promote singing.

The invention will be more fully described in connection with the accompanying drawings, wherein:

Fig. 1 is a diagrammatic representation of a two-way carrier communication system employing a bilateral modulator of the invention at each terminal;

Fig. 2 is a diagrammatic representation of a 21-type repeater circuit which may be considered as a prototype of the two-way carrier circuit of Fig. 1; and

Figs. 3 and 4 disclose modified forms of the bilateral modulator of Fig. 1 characterized by the use of the principle of carrier suppression.

In the circuit of Fig. 2 signal currents to be amplified may be derived from a circuit not shown connected to conductors 1 and flow in a circuit which includes the four line conductor windings of the balanced network or hybrid coil represented generally by reference numeral 2. This current induces an electromotive force in the remaining windings 3 of the balanced circuit, which elec-

tromotive force or corresponding current is amplified in amplifier or repeater 4 and reimpressed on the line through circuit 5. The mode of connection of circuit 5 to the line is such that the currents derived from said circuit and flowing in opposite directions in the line through the respective pairs of line windings of the hybrid coil effect a balance of magneto-motive forces in the input coils 3 of the repeater so that amplification may occur as above, without regeneration or singing. The amplified current flows in conductors 6 which constitutes an extension of conductors 1, pairs of conductors 1 and 6 constituting the complete transmission line. The currents incoming from the opposite direction, that is, currents derived from circuits, not shown, which are connected to conductor 6, are transmitted through the hybrid coil and amplifier in exactly the same way as has been described with reference to the currents derived from conductors 1.

The arrangement of Fig. 2 therefore constitutes a two-way transmission circuit employing a single non-singing amplifying device, and the device 4 with its immediately associated circuits may be considered as a bilateral amplifier or repeater, although the amplifying or repeating element per se is unilaterally conducting. The system, when used as above, that is, as an amplifier rather than as a frequency translating means as in the invention to be next described, is well known in the communication art as a 21-type repeater. It is described in detail in a paper by Gherardi and Jewett in the Transactions of the American Institute of Electrical Engineers, volume 38, part 2, beginning in page 1287. Attention is called especially to Fig. 29 in page 1324, and the context.

The system of Fig. 1 comprises a two-way carrier transmission circuit employing a bilateral modulator at each terminal. The circuit arrangements at each terminus of Fig. 2 simulate in their operation those of Fig. 1. For example, it may be considered as a system like that of Fig. 2 modified by the replacement of the amplifier element by a modulator-demodulator, the system otherwise being modified as necessitated by the frequency translation which attends modulation. Reference numeral 7 represents a transmission line connecting terminal stations disclosed at the right and left. Each terminal station involves apparatus and circuits for translating relatively low frequency signal waves into carrier modulated signal side bands, the transmission line accordingly being adapted to transmit such high frequency currents. The transmission line may equally well be adapted for simultaneously transmitting low frequency currents, independence of function of the high frequency and low frequency circuits contemplated by such composite use being insured by a high pass filter HP_2 inserted in the high frequeny circuits immediately adjacent the transmission line at either terminal, and by corresponding low pass filters LP similarly inserted in low frequency lines 8 connected to the transmission line.

The two terminals of the two-way system are identical, although the showing in the drawing of the right terminal is made more diagrammatic than the left terminal. The remainder of the description of Fig. 1 will accordingly be confined to the left terminal, the labeling of the parts described being duplitcataed at the right terminal except where made impossible on account of the diagrammatic showing thereof.

These circuits may be best described by an analysis of their method of operation having in mind the functional relationship of the circuits to the 21-type repeater circuit of Fig. 2 above described. Signal waves, later destined to modulate a carrier wave to produce the transmitted side-bands are derived from circuit 9 and are impressed through transformer 10, which may be dispensed with on occasion, through low pass filter LP_2 on the modulator represented generally by M.

The circuit from low pass filter LP_2 through the modulator may be traced as follows: Upper conductor of circuit 11, the right hand conductor of circuit 12, the lower of the two input coils 13 of the modulator, the conductor 24, coil 23, ground 26, and by the left hand conductor of circuit 12 back to filter LP_2. A potential derived from these signal waves is impressed on the modulator on account of the coupling between the lower coil 13 and lower coil 25. Carrier current for the modulator is impressed on the upper input coil 13 of the modulator from its source C through circuit 17, amplifier A, if amplification is desired, transformer 18, high pass filter HP_1, and circuits 15 and 14, in that order. The circuit for the carrier current is completed from the upper input coil 13 through conductor 24, coil 23 and ground 26. By analogy with the conditions affecting the operation of an ordinary hybrid coil arrangement current is unable to flow in either direction through the network comprising coils 13 and 25 between circuit 12 and circuit 14, and of course low frequency signaling current cannot be transmitted through filter HP_2. Accordingly the circuit arrangements described effectually suppress both the carrier and modulating currents and keep them from flowing in transmission line 7.

The filters LP_1, LP_2, HP_1 and HP_2 may conform in type and function to filters conventionally used to perform similar specific

functions. Examples of filters which may be used in the system of Fig. 2 are illustrated in U. S. Patent 1,227,113 to Campbell, May 22, 1917. Similarly the carrier source is not specific to this system but may be adapted from conventional practice. For example, the source may be a vacuum tube oscillator of the type disclosed in the U. S. patent to Hartley 1,356,763, October 26, 1920.

The input circuits of thermionic electric discharge devices 20 and 21, comprised in the modulator M, are related to each other and to their immediately associated circuits in a manner quite similar to that of the well known push-pull amplifier, as described for example, in U. S. patent to Colpitts, 1,128,292, February 16, 1915. However, the output circuits of the two devices are somewhat differently related than in the circuit of that patent, in that the output wave is derived from a common portion of the anode-cathode circuits of the two devices instead of from a circuit differentially related to the devices. It results from the particular relation of elements disclosed that any wave impressed on the modulator circuit from coil 13, and therefore impressed differentially on the internal input circuits of the devices mutually compensate or balance each other in the common output coil 22 and are therefore not transmitted to the external output circuit connected to coil 23 which is coupled to said output coil.

The same is true of powers of such impressed waves and odd order modulated side bands, that is, side bands whose frequencies are indicated by expressions like $2P \pm Q$, $2Q \pm P$, $4P \pm Q$ and $4Q \pm P$, in which P and Q represent the carrier and modulator frequencies.

On the other hand, harmonic components of the impressed waves, resulting from modulation, and also even order side bands such as are indicated by expressions like $P \pm Q$, $2P \pm 2Q$, etc., are not balanced out but occur in coil 22 and are transmitted through coupled coil 23.

As a practical matter, the only output products of the modulator which are utilized are second order side bands. They are transmitted from the terminals of coil 23, through conductor 24 to impress a difference of potential between ground and the input circuit to the modulator. The connection to the input circuit is at the midpoint of the coils 13 so that the two currents flowing in relatively opposite directions from the point of connection, if equal, cause equal electromotive forces to be induced in coils 25 coupled with coils 13, so that by the circuit relationships so far pointed out modulation of the carrier by the signal wave may be effected without regeneration or singing on account of the modulator circuits. The resistances shown in shunt to certain of the coils are approximately equal to the impedances of such coils. The use of such resistances has been found to improve the frequency characteristics of the coils.

Although a single thermionic discharge device would be adequate to form the requisite modulating functions, the combination of two such devices in push-pull relation is necessary to insure a condition of balance and therefore an avoidance of singing. Equality of the currents in coils 13 is insured by the electrical symmetry of the paths of current flow in either direction to ground 26 from the point of connection between such coils. That is, the filters LP_1 and HP_1 with their immediately associated terminating circuits have the same impedance characteristics as the similar combination of filters LP_2 and HP_2 and their immediately associated circuits.

In the particular modulator organization above described, the circuits containing the filters LP_1 and HP_1, and similarly in the case of filters LP_2 and HP_2 have their terminating elements at the modulator terminals in parallel. In order that these circuits, including their filter networks, may be substantially functionally independent, the terminating network elements on the sides toward the modulator should have high impedance outside the transmission ranges of the filters. If the relation of these filters to each other were such that the filter terminations were presented to the modulator in series as might well be the case in an alternative arrangement, these terminations would have to have low impedance outside of the transmission ranges.

With respect to the complemental function of the modulator, that is, with respect to its use as a demodulator of incoming side bands to reproduce a signal, the operation is identically the same so far as concerns the modulator per se and its immediately associated circuits, the current to be combined with the carrier in this case being derived from the transmission line and being transmitted to circuit 12 through transformer 19 and filter HP_2 instead of from the circuits at the left of the connection points of circuit 12.

The system may be adapted for single or double side band transmission, without qualification of the inherent principle of the invention or its method of operation, by proper design of the high frequency filters HP_1 and HP_2. Although, of course, with respect to the transmitted wave the filter HP_2 is solely responsible for the choice of frequencies transmitted, any modification of this filter, as to determine whether a single side band or both side bands should be transmitted, should be duplicated in filter HP_1 to observe the essential symmetry.

Figs. 3 and 4 illustrate slightly variant

forms of a bilateral modulator system of a novel type, alternative to that illustrated in Fig. 1. Although these modulators and their immediately associated circuits are not illustrated as adapted without change for substitution for modulator M in the system of Fig. 1, it is obvious that as far as regards their method of operation, they are equally well adapted for use therein and could be so used with obvious modifications.

The circuits of Figs. 3 and 4 differ essentially from each other only in that Fig. 3 illustrates a direct coupling of the input circuits to the modulator devices per se, in contradistinction to the inductive coupling through two-winding transformers of Fig. 4, and similarly functioning elements are similarly labeled. Fig. 4 shows in detail a practicable design of filter circuits that may be used in a system of that figure or in the system of Fig. 3 wherein the similar elements are indicated diagrammatically only.

In the type of bilateral modulator disclosed in Figs. 3 and 4 carrier suppression occurs on account of the symmetrical relation of coil 27, by means of which the carrier current derives from circuit 28 is impressed on the two electric discharge elements 29 and 30 of the modulators, with respect to such elements. The signal and modulation side bands are each impressed in the same way on the modulators and differentially with respect to its two electric discharge elements. The low frequency signal currents are transmitted through low pass filter LP_3, the modulation side bands being similarly transmitted through filter HP_3.

The circuits of Figs. 3 and 4 differ, other than by the particular means for carrier suppression, from the modulator of Fig. 1 in that they use two-element modulator devices per se. This considerably simplifies the circuit and avoids the necessity for the reentrant connection, as in the modulator of Fig. 1. The operation of the circuits of Figs. 3 and 4 also differs from that of Fig. 1 in the modulation products which are balanced out. The present considered circuits balance out, in addition to the carrier, the even harmonics of the impressed signal and side bands but permit to flow in the output circuit both even order side bands, and odd order side bands of the type represented by $2P \pm Q$, etc., that is, the types of odd order side bands that would be most useful in practice. For a complete treatment of high order modulation, especially third order modulation, reference is made to U. S. Patent to Peterson 1,678,163, granted July 24, 1928.

By reason of this diversity of function, the systems of Figs. 3 and 4 may be alternately used, for example, for either the more conventional type of modulation, here denominated the second order, or the most desirable type of odd order modulation, that is, third order modulation. If third order modulation is used, of course, the filters HP_3 must be adaptable for a much wider range of transmission than for the other case.

The novel features inherent in the invention are pointed out in the accompanying claims.

What is claimed is:

1. In combination, a transmission line, means for impressing relatively low frequency waves on said line, means for impressing carrier waves on said line, a modulating device, circuit means connecting the input circuit of said modulator to said line, and circuit means connecting the output circuit of said modulator to said line contiguous to said input circuit connecting means, said input and output connecting circuits being conjugately related so that output energy produces substantially no difference of potential between the input terminals of the modulator device.

2. A modulator circuit comprising a low frequency source, a carrier frequency source, a modulator, a common terminal circuit for impressing the waves from said sources and for deriving the waves from said modulator, and means preventing regenerative amplification in said modulator.

3. A two-way low frequency line, a two-way high frequency line connected thereto, modulating means having its input circuit connected to said lines at their junction points and its output circuit also connected to said lines but conjugately with respect to said input circuit.

4. In combination, a transmission line, means for impressing relatively low frequencies on said line, means for impressing carrier waves on said line, a modulating-demodulating device comprising an input circuit, a circuit connecting said input circuit to said line, and a circut for impressing output currents of said device on said line, said last mentioned circuit comprising one connection directly to one side of the line and a second connection to a point in said input circuit such that current flowing therefrom in opposite directions in said input circuit to the point of direct connection produces a balance of output electromotive forces, whereby said device is made non-regenerative with respect to said output currents.

5. A combination defined by claim 4 comprising additionally, a frequency discriminating network in said line on either side of said connecting circuit and adapted respectively to transmit the low frequencies and the desired modulator output frequencies to the exclusion of the remaining frequencies, and similar networks in the portion of said

connecting circuit on the opposite side of said input circuit from said line whereby the output current flowing in the two portions of the input circuit and through the two pairs of frequency discriminating networks encounter impedances of like characteristics.

6. A combination defined by claim 4 comprising additionally, a frequency discriminating network in said line on either side of said connecting circuit and adapted to respectively transmit the low frequencies and the desired modulator output frequencies to the exclusion of the remaining frequencies, similar networks in the portion of said connecting circuit on the opposite side of said input circuit from said line whereby the output current flowing in the two portions of the input circuit and through the two pairs of frequency discriminating networks encounter impedances of like characteristics, and means for impressing a desired incoming modulating side band current at the opposite terminal of said line.

7. A two-way low frequency transmission line, a two-way high frequency line connected therewith, frequency discriminating networks in the respective low frequency and high frequency lines, a two-terminal modulator-demodulator device having an input and output circuit, means connecting one terminal of said input circuit directly to said lines at one of their junction points, means for connecting the other terminal of said lines at the other junction point through a balancing circuit adapted to simulate the impedance characteristics of said lines and their included networks, means for impressing carrier waves on said high frequency line of said device, and means associated with said device whereby its output circuit is connected to said lines both directly and through said balancing circuit but conjugately with respect to said input circuit.

8. In a modulator-demodulator in combination, two similar two-element electric discharge modulator-demodulator devices each comprising a cathode and anode, a circuit connecting the cathode and anode of each said device and comprising an individual portion and a portion common to both said connecting circuits, means associated with said common portion for impressing a carrier wave of like phase on the anodes of said devices, and means associated with the individual portions for, in common, impressing modulating and modulated waves differentially on said anodes and for similarly deriving the resultant modulated and reproduced modulating waves from said devices.

In witness whereof, I hereunto subscribe my name this 20th day of March, 1929.

EUGENE PETERSON.