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H. S. BLACK

CARRIER WAVE SIGNALING SYSTEM

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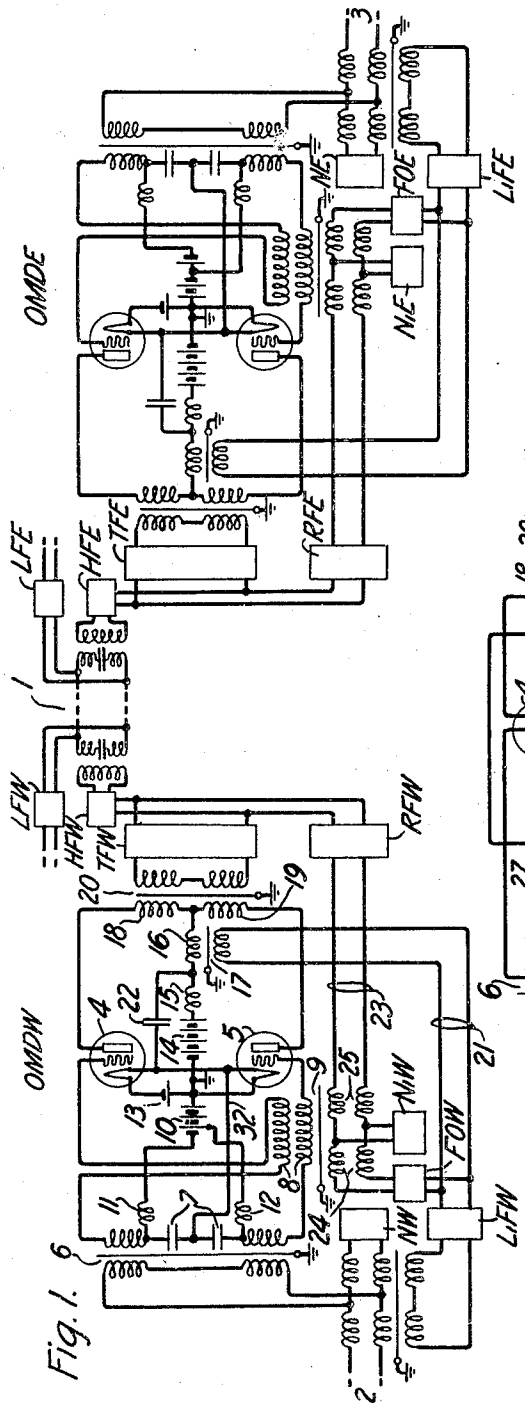


Fig. 1.

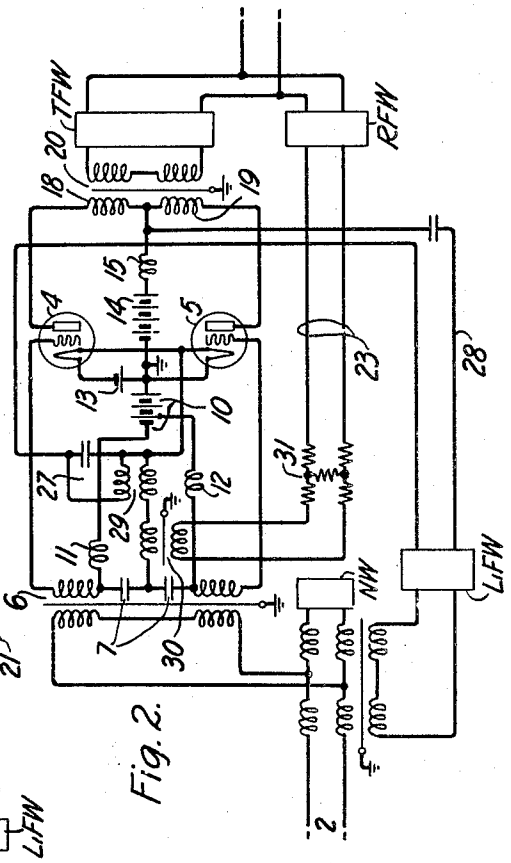


Fig. 2.

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UNITED STATES PATENT OFFICE.

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CARRIER-WAVE SIGNALING SYSTEM.

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This invention relates to carrier wave signaling systems and more particularly to terminal arrangements for associating the sending and receiving branches of a two-way carrier wave signaling circuit with each other and with a common transmitting line or medium.

The expression "carrier wave system" is used here and throughout the specification and claims to define broadly a system in the operation of which signal variations are transmitted as modulations of a single frequency wave. The resultant modulated wave may be transmitted as an electric current by a method that may here be denominated "line-wire carrier wave" signaling, or etheric space instead of a current conducting means can be used as the transmitting medium as in "radio carrier wave" signaling. Although this invention may perhaps be most usefully employed in a line-wire carrier wave system, the principles thereof are applicable generally to carrier wave systems of either type. Also a two-way circuit, that is, the minimum prerequisite for conversation, will be assumed as the practical signaling unit, the terms "single" and "multiple" or "multiplex" being used to indicate one or more than one of such units.

One object of the invention is to provide circuits for a single channel carrier wave signaling system which combines relatively great efficiency, simplicity and low cost with adequate protection against the various types of interference which are incidental to the operation of such systems.

In the past, it has been recognized that certain economies could be effected by the use of multiple channel carrier wave signaling systems, especially of the line-wire type, as compared with single channel systems. That is, the use of a single channel system has been found to require the use of circuits and apparatus that could be used in common for a plurality of such single channel systems, so that considerations of economy have urged the use of a plurality of such single channel systems, combined into a unitary multiple channel system. The practical result has been that the installation of carrier wave systems has had to be postponed to the time when the installation of a multiple channel system could be justified.

A further object of the invention is to make the economy and other advantages of carrier wave signaling systems realizable in smaller units than has heretofore been possible, and specifically to provide a single channel carrier wave signaling system in which the efficiency of operation, first cost, simplicity, etc. approximates that of an equivalent single channel circuit comprised within a multiple channel carrier wave system.

One way to promote economy in the use of material and at the same time promote economy of utilized energy in the single channel carrier wave system is to transmit a pure modulated wave in each direction, use the same carrier frequency for both directions of transmission, and use a single local carrier source at each terminus to supply these carrier waves for transmission and reception. These features are adopted in the system of the present invention in which, however, even further economies in use of material are effected by using this source also as a modulator and as a demodulator. In order that the carrier frequency may be suppressed, a balanced arrangement is used. The arrangement accordingly is a self-oscillatory balanced-modulator-demodulator. Three-electrode electric discharge tubes are used, only two such tubes being required at each terminus.

In order to avoid the hazard of interference between the transmitting and receiving functions, which is incurred by reason of the superposition of portions of the corresponding circuits, these two circuits are made effectively independent by the following expedient. When the balanced tube arrangement is used for modulation, the modulating wave is impressed differentially on the control electrodes and the modulated wave is similarly derived differentially from the anodes, the common portions of the control electrode-cathode and anode-cathode circuit being correspondingly used when the arrangement is being used for demodulation.

Features that tend further to simplify the circuits and accordingly to reduce the cost, are the use of the feed-back circuit employed in the generation of oscillations in common for that purpose and for transmitting the demodulated low frequency wave, and the use of a common transformer for impressing

the incoming side band currents and the fedback carrier current on the input circuits of the tubes.

The invention both as to its principles and its practical embodiment will be better understood by reference to the following detailed description taken with the accompanying drawings in which;

Fig. 1 illustrates a complete single channel system of the invention, and

Fig. 2 illustrates in detail an alternative form of circuit that may be used at either terminus of the system.

In the description which follows the elements of the system will be identified as far as practically possible by literal designations which are suggestive of their respective functions or the termini at which they are located. Elements which are duplicates of each other and located at the same terminus, so as to require the use of the same literal designation, will be differentiated by the use of different subscripts.

Referring to Fig. 1, the circuits at the left of this figure are related to one terminus designated for convenience as the west, of a single channel carrier wave system, and the circuits at the right of the figure are correspondingly related to the other, the east, terminus of the system. The circuits at the respective termini are each connected to the transmission path 1, which is here illustrated as an electric current conductor but which might equally well comprise transmitting and receiving antennæ and an intermediate ether link. The system is composited for simultaneous low frequency and carrier wave communication. This is accomplished by carrier composite sets, the set at the western terminus comprising the low frequency filter LFW and the high frequency carrier filter HFW, and the set at the east terminus correspondingly comprising the low pass filter LFE and the high frequency filter HFE. The low pass filters are positioned in the telegraph or telephone branch, and the high pass filters in the carrier wave branch, of the transmission line. These filters accordingly effectively separate the currents corresponding to the frequencies used in these respective types of transmission. Obviously, the system could be used for carrier wave transmission only, in which case these filters could be dispensed with.

One complete channel system is disclosed. This channel comprises the following elements which may function in like sequence in a two-way conversation initiated at the western terminus; low frequency line 2, oscillator-modulator-demodulator, OMDW, transmission high pass or band pass filter TFW, the high pass or band pass filter HFW of the composite set common transmission line 1, the high pass or band pass filter HFE, of the composite set at the east terminus, the receiving high pass or band pass filter RFE, the oscillator-modulator-demodulator OMDE, and the low frequency line 3.

The operation of this channel for eastward transmission is as follows: The low frequency modulating currents in line 2, which for example may be connected to a central telephone office, are intermodulated with a carrier current in circuit OMDW which, as will appear more fully later, embodies a unitary self-oscillating balanced-modulator-demodulator. Only one of the two side bands, for example the upper, is transmitted from the western station. This side band is transmitted through filters TFW and HFW to line 1 and thence to the east terminus where it is transmitted through filters HFE and RFE to circuit OMDE, where it is demodulated to reproduce the modulating wave, which is transmitted to indicating circuits, not shown, by low frequency line 3.

For the opposite direction of transmission, a similar sequence of operations occurs whereby modulating currents in circuit 3 are operated upon by a similar sequence of steps to reproduce this modulating wave in circuit 2. Accordingly the circuit OMDE for this direction functions as a modulator instead of as a demodulator and correspondingly circuit OMDW functions as a demodulator instead of as a modulator. Further, for this direction of transmission, the lower instead of the upper side band is transmitted. Since the modulation is attended by the suppression of the unmodulated carrier, filters TFW and TFE need to be adjusted only to discriminate between the side bands. Filters RFW and RFE are not concerned in this operation. These filters however, are almost universally used in systems of this general type, their use being justified on account of their contribution to the ease of impedance matching in various parts of the system, which matching is necessary for the most efficient transfer of energy between sections of the circuit having different impedances. In view of the use of a pair of filters such as TFW and RFW, at each terminus, the composite filters HFW and HFE are not essential for separating the frequencies used in carrier wave signaling from those used in low frequency signaling. They, however, like filters RFW and RFE, are almost universally used, their use being justified by reasons similar to those applied above to filters RFW and RFE.

Selection, rather than balance, at the junctions of the transmission line and the circuits at the two termini are relied upon to prevent interference at these points between the transmitting and receiving circuits. This is made possible, in spite of the use of the same carrier frequency, by the use of different side bands for opposite direc-

tions. The system of the invention is thus seen to possess the advantages of the staggered carrier frequency system in which carrier frequencies used for transmitting in one direction are intermediate those used in the other direction, but the invention makes possible a smaller frequency interval between transmissions than would be required in such a staggered frequency system. The principle utilized in the invention may be termed staggering of the signaling currents.

Although advantages inhere in this type of staggered arrangement, when carrier suppression is used, on account of the expedient thereby made possible of using a single local source to supply the carrier frequencies, for both directions of transmission, the novel features of this invention relate particularly to an arrangement of circuits whereby this local source is also used as a modulator and as a demodulator. The detailed circuit arrangements which make this possible will now be described. It will be understood that in Fig. 1, the circuits are identical at the two termini except only for the differences in transmission ranges of certain of the filters resulting from the staggered side band operation. Accordingly although the detailed description will refer specifically to the circuits of the west terminus, the elements of which will be correspondingly labeled in the drawing, it will be understood to apply equally to both termini.

The common translating circuit used in combination as an oscillator, modulator and demodulator, comprises a balanced electric discharge tube circuit including the two electric discharge tubes 4 and 5 which may be of the usual three-electrode type including a cathode, an anode and a control electrode or grid. The cathodes of these tubes are connected together and by means of circuit 32, to the mid-point of the circuit constituted by the secondary windings of the input transformer 6, blocking condensers 7, and the secondary winding 8 of transformer 9, the last mentioned transformer, as will be explained later, being used for impressing the incoming side band and the fed-back carrier wave on the grids of the two tubes. The grids of the tubes are connected to the respective opposite terminals of this circuit.

The grids are biased by battery 10. The grid biasing circuit for the tube 4 can be traced from the grid, through one of the secondary windings 8 of transformer 9, through the upper portion of the secondary winding of transformer 6 and through high frequency choke coil 11, to the negative end of the battery 10, and thence to the cathodes. The grid biasing circuit for tube 5 can be similarly traced from its grid through the other secondary winding of transformer 9, through the lower secondary winding of transformer 6, through high frequency choke coil 12, to a point in the battery 10 intermediate its ends, and thence to the cathodes. Different grid biasing potentials from battery 10 are used in the cases of the two grids for the reason that the cathode energizing battery 13 is so positioned relatively to the two grids and to the positive end of the battery 10 that the cathode of tube 5, on an average, is more negative with respect to the positive terminus of battery 10 than the grid of tube 4. This requires in a known instance, in order that the grids may be equally negative as compared with their respective cathodes, that one less cell of battery 10 be used for biasing the grid of tube 5 than for biasing the grid of tube 4.

The use of choke coils 11 and 12, the blocking condensers 7 and the use of a separate connection 32 directly from the cathodes to the secondary circuit of transformer 6, insures a complete independence of function of the grid biasing circuits and the circuits used for impressing variable potentials on the grids from the primary of the transformer 6.

The cathodes are also connected, through space current source 14, high frequency choke coil 15, primary winding 16 of transformer 17 and the two halves 18 and 19 of the primary winding of transformer 20, to the anodes of the two tubes. These circuits provide a path for the space current for the two tubes and also, by means of the primary winding 16 make provision for transmitting alternating current from the common portion of the anode-cathode circuits. These alternating currents comprise, among others, the carrier current and the demodulated low frequency current. The former is fed back to the input circuits of the tubes, through transmission circuit 21, oscillator filter FOW and transformer 9, to constitute the arrangement a balanced oscillator. The frequency of the oscillations are determined by the transmission frequency of the filter FOW in accordance with a principle described in detail in U. S. patent to Nichols 1,442,781 granted January 16, 1923. The demodulated current is transmitted through circuit 21, including low pass filter L, FW, to circuit 2. Condenser 22 in shunt to the battery 14 and high frequency choke coil 15 provides a by-pass circuit around the space current source for the alternating current, the choke coil 15 further preventing the flow of this current through this source.

The secondary windings of transformer 6 are wound in the same direction with respect to a reference point outside of and in the same line with said secondaries. The two portions 18 and 19 of the primary winding of transformer 20, the two portions of the secondary of this transformer, and the two portions of the primary of transformer 6 are similarly wound.

A circuit 23 provides a path whereby incoming modulated side band is impressed on the balanced tube arrangement. These incoming currents flow from transmission line 1 through filters HFW and RFW, the transmission line 23, and the transformer 9 whereby they are impressed by means of secondary windings 8 on the grids of the two tubes.

The circuit for impressing these incoming currents on the grids and the circuit for correspondingly impressing the fed-back carrier current on the grids are related through the hybrid coil arrangement comprising windings 24 and 25 and the balancing network N, W in such manner that the currents in either one of these circuits cannot be impressed on the other circuit. The arrangement is similar to the alternative form of hybrid coil arrangement conventionally used, for example, in two-way repeaters. The principle of operation and the ultimate function of the arrangements is the same in the two forms.

Although separate secondary windings 8 are used for impressing currents on the grid circuits, these windings are so arranged that the result is similar to that using the more conventional arrangement in which the currents are impressed on the common grid cathode lead for the two tubes. The specific arrangement disclosed is described in detail and claimed in U. S. patent of Coram 1,568,963 granted January 12, 1926. In brief, this arrangement is used to insure that the full force of the voltages is applied to the grids. By the alternative arrangement, a portion of the currents are shunted to ground (since the cathodes are grounded) by reason of the capacity to ground of the low frequency modulating circuit and of the capacity to ground of the secondary windings of the transformer whereby these modulating currents are impressed on the grids. This results in a decrease in the potential actually impressed. The arrangement disclosed accordingly makes possible the same ultimate result with a smaller amount of high frequency impressed energy.

Besides the common use of the same translating devices for the oscillator, modulator and demodulator functions, Fig. 1 also illustrates the other remaining two features briefly described in the statement of the invention by which certain economies in circuits and apparatus are effected. These features comprise the use of circuit 21 in common for transmitting the demodulated low frequency wave and for feeding back the carrier wave, and the use of the single transformer 9 for impressing the incoming currents and the fed-back current on the balanced devices.

It is a characteristic of a properly balanced circuit of the type illustrated in Figure 1 that the output coils constituted by the primary windings 18 and 19 of transformer 20 and the input coils constituted by the secondary windings of transformer 6 are balanced as to voltages applied in like phase on the two grids. Consequently, the circuits connected to the secondary of transformer 20 and to the primary of transformer 6 are balanced as to these voltages. However, these voltages impressed in like phase on the grids are repeated in amplified form into the two anode branches which includes the common portion comprising the feedback circuit. By adjusting the transmission range and number of sections of the filter FOW so as to feed back in proper phase a component corresponding to the desired carrier frequency, the balanced tube arrangement may be caused to oscillate independently at this frequency. Since the path which the oscillations follow is, as above stated, neutral with respect to the input and output circuits connected to transformers 6 and 20, the waves locally generated are confined to the balanced tube arrangement and are therefore prevented from passing into either of these circuits.

The operation of the arrangement as a modulator and demodulator will be clear from the following description of the path taken by the currents in the course of transmission and reception.

The modulating currents from low frequency circuit 2 are impressed on the primary winding of transformer 6 and, on account of the connection of the secondary windings to the grids, cause the potentials of the grids of tubes 4 and 5 to vary in opposite directions to produce corresponding impedance variations in the anode-cathode paths of these tubes. In this manner, the normally balanced arrangement is unbalanced to an extent dependent on the amplitude of the impressed low frequency variations and the modulating currents are accordingly transmitted to the output circuit connected to transformer 20 as variations in the amplitude of the high frequency current produced by the balanced tube arrangement by virtue of its oscillatory function, which frequently currents are ordinarily balanced so as not to appear in the output circuit.

The incoming side band currents which pass through the filters HFW and RFW are impressed through circuit 23 and transformer 9 in like phase on the two grids. These side band currents are combined with the carrier current in the same manner as if such carrier currents were independently impressed in like manner on the grids. The balanced arrangement, when used for demodulation, accordingly functions merely as a parallel arrangement of two conventional amplifier-modulating circuits. Although the

individual portions of the output circuits of the two tubes are balanced with respect to any electrical variations impressed in like phase on the grids, the common portions of the output circuits are not similarly balanced, therefore combination frequency components resulting from interaction of the carrier and side band currents appear in this common portion which includes primary winding 16. By reason of the fact, and to the extent that, the individual portions of the output circuit are balanced with respect to the common portion, the combination currents impressed on this common portion are superposed in additive relation in this winding. Filter L_1FW suppressed all of these combination components except the desired reproduced modulating wave and transmits this component to circuit 2.

Outgoing modulating currents which flow through filter L_1FW are not transmitted to the circuits connected to the secondary of transformer 20 on account of the balanced relation of the output circuits of the tubes. For the same reason, and also by reason of the unilateral conducting properties of the tubes, these currents are prevented from appearing in the input circuits of the tubes to set up a singing condition of the circuits related to the tubes.

In considering the operation of the arrangement for modulation and demodulation, it should be noted that when a balanced tube arrangement is used for modulation, the modulating wave is impressed differentially on the grids and the resultant modulated wave is derived differentially from the anodes, while, when the same tubes are used for demodulation, the incoming side band currents are impressed in the same phase on the grids and the resultant reproduced modulating current is derived from a circuit which is balanced with respect to the two anodes. This means that the balancing arrangement which insures carrier suppression during the modulating operation is also utilized to insure that the input and output circuits are balanced with respect to the incoming side band currents so that these currents cannot flow in the low frequency circuit 2 or be transmitted without demodulation to the output circuit connected to the secondary and transformer 20. Accordingly, although a common means is used for the modulating and demodulating functions, the circuits as a whole which are used for these respective functions are effectively distinct and individual.

The circuits of Fig. 2 may be substituted for the circuits at either of the termini of the system of Fig. 1. They differ only in certain specific details from the one above described with reference to Fig. 1. The following description will be confined to these differences. The remaining elements which are similar to those of Fig. 1, are similarly labeled.

In the system of Fig. 2, the feed back current flows from the cathodes through tuned circuit 27, through the end impedance of low pass filter L_1FW and conductor 28 to the junction of windings 18 and 19 of the primary transformer 20 and thence to the two anodes. Transformer 29 couples this circuit to the common portion of the grid-cathode circuits of the tubes. This transformer is individual to this feed-back circuit, a separate transformer 30 being used for impressing the incoming side band current on the grids. The balanced tube arrangement oscillates by virtue of the feed back function at the natural frequency of the tuned circuit 27. Accordingly, the operation of the tubes as an oscillator simulates that of the conventional tuned output oscillator. This system has the feature, common to it and to the system of Fig. 1, of utilizing a common circuit in part for providing the feed back and for transmitting the demodulated low frequency wave, but it does not have the feature, which is comprised in the system of Fig. 1, of using a common transformer for impressing the fed-back and incoming side band currents on the tubes or the means, also comprised in the system of Fig. 1, for impressing these currents directly on the grids.

Impedance device 31 in circuit 23 is a padding element. Its use may be dispensed with on occasion. It is useful where it is desired to vary the attenuation of currents flowing therethrough without affecting the impedance of the circuit in which it is contained. For a typical example of the use of such padding elements, reference is made to United States patent to Wilbur 1,498,941 granted June 24, 1924, in which see elements 107 to 110 of Fig. 1. For a theoretical explanation of the function of such a device and particularly of the type in which the attenuation can be made variable, see United States patent to Vennes 1,472,507 granted October 30, 1923.

In the circuit of Fig. 2 reliance must be had on the selective properties of filter RFW and tuned circuit 27 to prevent interference between the carrier current and the incoming modulated currents, whereas in the system of Fig. 1, additional safeguards are provided by reason of the balanced relation of the circuits associated with the hybrid coil arrangement. It has been found however, that this system of Fig. 2, although perhaps less efficient in this respect than that of Fig. 1, is completely operative and substantially as efficient as arrangements conventionally used in single channel systems.

Several filters have been diagrammatically shown in the drawing. The details of these filters have not been illustrated because their design and principles of operation are so

well known to those skilled in the art. However, if more detail as to these filters is required it may be obtained by reading U. S. patent to Campbell 1,227,113 granted May 22, 1917 which contains a description of various types of filters adaptable to use in the systems of this invention.

While the invention has been illustrated as embodied in a limited number of forms, it will be understood that it is equally applicable to other forms and to variations in the details of the form illustrated, without departing from the spirit of the invention as defined in the appended claims.

In the claims, a pure modulated wave is a modulated wave which contains no unmodulated component. It may consist of one or both side bands. Also in the claims, the reference to a single side band wave is intended to define a wave which has only one instead of both side bands without regard to whether or not there may be unmodulated carrier current.

What is claimed is:

1. In a two-way carrier wave signaling system, a station comprising means for generating a carrier wave, means for generating a modulating wave, means for modulating said carrier wave in accordance with said modulating wave, means for selecting from the output wave of the modulator components including a single side band and for transmitting said components, and means for demodulating an incoming side band having the same carrier frequency but of opposite sign to the transmitted side band, said carrier current generating, modulating, and demodulating means employing a common electric discharge structure.

2. A station of a two-way carrier signaling system comprising means for generating a modulating wave, means for generating a carrier wave, modulating means utilizing said waves for generating a pure modulated wave, means for selecting and transmitting one side band from said pure modulated wave, and demodulating means utilizing the wave from said carrier source and an incoming side band which is based on the same carrier frequency but is of opposite sign as compared with the transmitted side band, for reproducing a signal wave, said carrier wave generating means, said modulating means, and said demodulating means employing a common electric discharge structure.

3. A station of a two-way carrier wave signaling system comprising a common means for generating a carrier modulated wave consisting of side bands of frequencies $p+q$ and $p-q$, in which p and q represent respectively the carrier and modulating frequencies and for demodulating incoming carrier modulated waves having frequencies corresponding to one of said side bands, said common means comprising a pair of electric discharge devices, each having an input and an output circuit, a feed-back circuit from the output circuits collectively to the input circuits collectively, an independent circuit for impressing modulating currents on the input circuits, and an independent circuit for deriving resultant carrier modulated currents; said input, output and feed-back circuits being so related to each other and to said independent circuits that when no modulating current is being impressed no current flows in said independent circuits.

4. In a high frequency signaling system, a pair of electric discharge translating devices, each having an input circuit and an output circuit, a feed-back circuit from the output circuits collectively to the input circuits collectively and containing a filter network whose transmission range includes the desired generated frequency and a number of sections such that said desired frequency is fed back in the necessary phase relation to insure the setting up of stable oscillations at that frequency in the system, an independent circuit for impressing electrical variations on the input circuits, and an independent circuit for deriving electrical variations from the output circuits, said input, output and feed-back circuits being so related to each other and to said two independent circuits that when no variations are impressed on the first-mentioned independent circuit, no current can flow in the second-mentioned independent circuit.

5. The combination specified in claim 4 including a source of modulating current in the first-mentioned independent circuit.

6. A combined balanced self-oscillatory modulator-demodulator comprising in combination a pair of electric discharge translating devices each having a cathode, an anode and a controlling electrode, a circuit connecting the cathode and controlling electrode of each device, a circuit associating the cathode-anode circuits including a common portion and a portion individual to each anode, the impedance constants of said devices and of said connecting and associating circuits being such that the pair of controlling electrodes and the pair of anodes are each balanced with respect to currents impressed in like phase on the two controlling electrodes, a feed-back circuit containing frequency determining elements connecting said common portion of the cathode-anode circuits and said connecting circuits in energy-flow relation and so arranged as to impress feed-back current in like phase on said controlling electrodes, means for impressing modulating current in opposite phase on said controlling electrodes, means

for deriving modulated currents from the individual portions of the cathode-anode circuits, means for impressing incoming modulated currents in like phase on the controlling electrodes, and means for deriving demodulated low frequency currents from the common portion of the cathode-anode circuits.

7. The combination specified in claim 6 including balance means for impressing the feed-back current and the incoming modulated current in like phase on the controlling electrodes, whereby neither of these currents can flow in the circuit of the other.

8. The combination specified in claim 6 in which the connecting circuits each contains a coupling coil adjacent the respective controlling electrodes for impressing the feed-back and incoming modulated currents on the controlling electrodes.

9. The combination specified in claim 6 in which the connecting circuits each contains a coupling coil adjacent the respective controlling electrodes and in which there is a hybrid coil circuit with balancing network for impressing the feed-back current and the incoming modulated current in balanced relation on said coupling coils.

10. The combination specified in claim 6 including an inductive coupling means between the feed-back circuit and said common portion, and in which the means for deriving demodulated low frequency currents from said common portion utilizes a portion of said feed-back circuit including said inductive coupling means.

11. The combination specified in claim 6 in which the connecting circuits each contains a coupling coil adjacent the respective controlling electrode, in which there is a hybrid coil circuit with balancing network for impressing the feed-back current and the incoming modulated current in balanced relation on said coupling coils, in which there is an inductive coupling means between the feed-back circuit and said common portion, and in which the means for deriving demodulated low frequency current from said common portion utilizes a portion of said feed-back circuit including said inductive coupling means.

12. A combined balanced oscillator-modulator-demodulator comprising in combination a pair of electric discharge translating devices each having a cathode, an anode, and a controlling electrode, circuits associating the cathode and controlling electrodes including a common portion and a portion individual to each controlling electrode, circuits associating the cathodes and anodes including a common portion and a portion individual to each anode, the impedance constants of the devices and of the two associating means being such that the controlling electrodes and the anodes are each balanced with respect to currents impressed on the common cathode-controlling electrode portion, a feed-back circuit containing frequency determining elements connecting said common portions in energy-flow relation, means for impressing modulating current in opposite phase on the individual cathode-controlling electrode portions, means for deriving modulated current from the individual portions of the cathode-anode circuits, means for impressing incoming modulated currents on the common cathode-controlling electrode portion, and a circuit for deriving demodulated low frequency currents from the common portion of the cathode-anode circuits.

13. The combination specified in claim 12 in which the feed-back circuit includes at least a portion of the circuit for deriving low frequency current, said feed-back circuit and said portion of the deriving circuit being included serially in the common portion of the cathode-anode circuits.

In witness whereof, I hereunto subscribe my name this 9th day of December, A. D., 1924.

HAROLD S. BLACK.