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DOUBLE BALANCED MODULATING SYSTEM

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FIG. 1

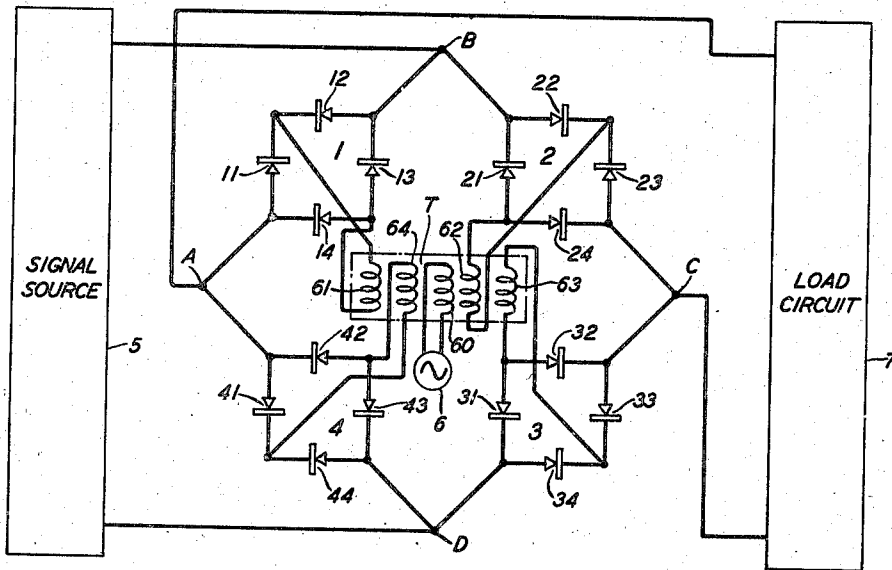


FIG. 2

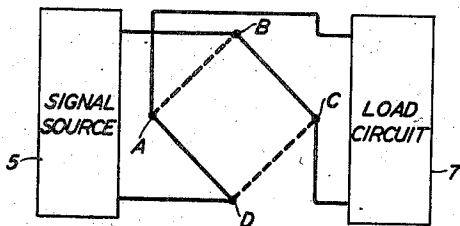
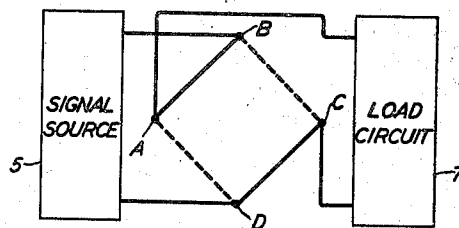


FIG. 3



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## UNITED STATES PATENT OFFICE

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## DOUBLE BALANCED MODULATING SYSTEM

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7 Claims. (Cl. 179—171.5)

This invention relates to modulating systems and more particularly to those systems in which transmission of the unmodulated carrier and of other undesired wave components is substantially prevented.

An object of the invention is to combine two impressed waves in a modulating, demodulating or detecting arrangement and to take off through a load circuit a desired combination product of the impressed waves while preventing the impressed waves and certain undesired combination products being transmitted to the load circuit. A system of the type to accomplish this result is commonly called a double balanced system. One of the properties of such a system is that the impedance facing each source of impressed waves is substantially unaffected by the presence of the load circuit or of the other source.

Double balanced systems are already known which employ a plurality of modulating elements together with several balanced inductive windings. Various attempts have been made to reduce these systems to a minimum number of elements, either of winding coils or modulating elements or both. U. S. Patent No. 2,025,158, issued December 24, 1935, to F. A. Cowan, is an example of a circuit employing a minimum number of elements, there being four balanced coils and four modulating elements.

Where a broad frequency band of transmission is involved in one of the impressed waves, as for example, in telephone transmission, or notably in television, the balanced coils may be called upon to carry a very wide range of signal frequencies. Consequently, the design and manufacture of the coils may become difficult and uneconomical. In all the double balanced systems of which I am aware, one or more coils are employed and several of these must carry the full range of impressed frequencies constituting the signal band.

Moreover, with the advent of inexpensive modulating devices, such as copper oxide rectifiers, the modulators are less costly than the coils. Accordingly, to reduce the cost of a double balanced system, particularly for broad band applications, it is expedient to increase the number of modulators employed where this makes possible a reduction in the number of coils required to carry the broad band of frequencies. In the system of the present invention sixteen modulators are employed with the result that all coils are eliminated from the portion of the circuit traversed by the broad bands of frequencies. While coils are still used in impressing the carrier wave upon the system, these coils need transmit only a single

frequency and the balanced coils do not exceed four in number.

In accordance with the invention there is employed an array of modulators, preferably rectifiers, arranged in the general form of a Wheatstone bridge, referred to hereinafter as the primary bridge. Each of the ratio arms of the primary bridge comprises a group of four rectifiers, themselves arranged in the form of a Wheatstone bridge, referred to hereinafter as a secondary bridge. The rectifiers in the secondary bridges are arranged to be biased simultaneously into a conductive condition or simultaneously into a non-conductive condition under the control of a carrier wave impressed upon one pair of diagonally opposite corners. The secondary bridge is connected into the primary bridge at its other pair of corners.

A multiwinding transformer is provided for impressing the carrier wave upon the four secondary bridges simultaneously in the proper phase relationship to each secondary bridge to make two opposite arms of the primary bridge conductive while the other two arms are made non-conductive. The signal source and the load circuit are connected in opposite diagonals of the primary bridge. The action of the carrier wave causes periodic reversals of the connections between the signal source and the load. These reversals occur at a rate determined by the carrier frequency, with the result that a pure modulated wave, free from the signal wave and from the unmodulated carrier, is transmitted to the load. The transformer need transmit only the carrier frequency since the signal wave and the side-bands of the modulated wave do not traverse any winding of the transformer.

The invention is described more in detail hereinafter with reference to the accompanying drawing in which:

Fig. 1 is a schematic representation of an embodiment of the invention; and

Figs. 2 and 3 are diagrams useful in explaining the operation of the circuit of Fig. 1.

Referring to Fig. 1, the junction points A, B, C, D, are the corners of the primary bridge. The primary bridge arm AB comprises a secondary bridge 1 which in turn is composed of the modulators or rectifiers 11, 12, 13, 14. Similarly, the arm BC comprises a secondary bridge 2 with the arms, composed of rectifiers 21, 22, 23, 24; the arm CD comprises bridge 3 with secondary arms 31, 32, 33, 34; and the arm DA comprises bridge 4 with secondary arms 41, 42, 43, 44. The sixteen rectifiers are preferably substantially alike, the

conductive direction of each being indicated by the direction of the arrow in the symbol for the rectifier according to a common convention. A signal source represented by the block 5 is connected in the primary bridge diagonal BD and a load circuit represented by the block 7 in the diagonal AC. A carrier source 6 is connected to the primary winding 60 of a transformer T having a plurality of secondary windings 61, 62, 63, 64.

The secondary windings are assumed to be wound all in the same direction so that the induced currents at any instant are to be taken as flowing either from bottom to top in all the coils, or else in the reverse direction. The actual direction of the windings in an embodiment of the transformer may, of course, be chosen in any convenient way and the connections between the coils and the bridge made such as to preserve the desired phase relationships as specified. To determine these phase relationships assume the currents to flow from the bottom to the top of all the coils. The connections to the secondary bridge are then to be made so that the current in coil 61 is opposed to the conductive direction of all the rectifiers comprising secondary bridge 1, the current in coil 63 is opposed to all the rectifiers in bridge 3, and the currents in coils 62 and 64 are directed in the conductive direction of the rectifiers in bridges 2 and 4, respectively.

In the operation of the system of Fig. 1, the primary bridge, except for the action of the carrier source 6, is balanced, so that the signal source 5 can pass substantially no current into the load 7. The carrier source by its action upon the rectifiers serves to unbalance the bridge first on one side and then on the other alternately, allowing signal current to pass to the load in spurts or pulses at a rate determined by the carrier frequency. Looked upon in another way, the bridge serves to reverse the connections between the signal source and the load at a rate determined by the carrier frequency. In still another view, the bridge acts as a commutator at the carrier frequency.

To consider the action of the system more in detail, suppose the carrier source at a given instant to be inducing a current from bottom to top of each coil 61, 62, 63, 64. Then, as noted above, the induced carrier currents oppose conduction, that is, block the rectifiers of secondary bridges 1 and 3 while aiding conduction in the rectifiers of secondary bridges 2 and 4. The result is a conductive path for the signal source through the primary bridge arms AD and BC to the load circuit, as indicated by solid lines in Fig. 2. It will be understood that the signal current is superimposed upon the carrier current in the conducting rectifiers. This condition of the circuit connection continues until the carrier wave reverses its polarity, at which time the secondary bridges 1 and 3 become conductive and 2 and 4 are blocked. The conductive paths in the primary bridge are now AB and CD as indicated by solid lines in Fig. 3. Comparing Figs. 2 and 3, it is easily verified that the action of the bridge under the control of the carrier wave is such as to reverse the connections between the signal source and the load circuit at each reversal of the carrier wave. The result of this action is a modulated carrier wave in the load circuit as is well known and which has been described, for example, in the patent to F. A. Cowan cited above. The action of the circuit of Fig. 1 in respect to its behavior as a double balanced circuit is fundamentally the same as that

of the systems disclosed in the Cowan patent, where it is explained that the signal source, carrier source and load circuit occupy mutually conjugate positions in the system. By virtue of their positions, simple transmission from the signal source into the carrier source or into the load circuit is substantially prevented; likewise, simple transmission from the carrier source into the signal source or into the load circuit is substantially prevented; and, finally, a source placed in the load circuit would be substantially incapable of simple transmission into either the signal or carrier source. By simple transmission here is meant transmission without frequency change and without the intervention of a modulation process of some sort. In the system of Fig. 1 it is evident that the carrier wave is balanced in each secondary bridge and thus the carrier source cannot send current to the signal source or to the load circuit at any time. In this connection it will be noted that the balance of the secondary bridges is not disturbed during operation of the system. In other words, the system functions to suppress the carrier wave.

To secure good balance, the rectifiers as above mentioned are preferably substantially alike. With present methods of manufacture this is not difficult, particularly where copper oxide rectifiers are used. If desired, each rectifier shown in Fig. 1 may be composed of two or more rectifiers in order to secure more nearly identical bridge arms. The use of a plurality of rectifiers is, of course, a means of obtaining an average operating characteristic which will match the average for another set of rectifiers more nearly than the characteristic of one rectifier matches that of another rectifier.

The windings 61, 62, 63, 64 should also be well balanced, that is, preferably all identical and symmetrically related to coil 60. These windings, however, as above mentioned, need only be efficient at a single frequency, that of the carrier. By virtue of the double balanced property the signal wave and modulated carrier wave do not traverse the windings.

It is evident that the signal source 5 and the load circuit 7 may be interchanged without affecting the essential operation of the circuit. The modulators may be of any desired or suitable type and need not be rectifiers. For example, they may be any devices which conduct unequally in two directions, and they may be controlled by grids in known manner, or by other means beside direct application of the carrier wave. The signal source may also be replaced by a source of modulated waves in which case the circuit of Fig. 1 may be operated as a detector or demodulator and the detected or demodulated signals received in the load circuit.

What is claimed is:

1. A modulating system comprising a plurality of rectifiers, a source of signal waves, a load circuit, a source of carrier waves, four branch circuits for carrier waves each coupled to said carrier source and each branch circuit including at least one of said rectifiers, a pair of carrier equipotential points in each of said branch circuits between which points no material potential difference is developed by waves from said carrier source, and a bridge array having the usual four bridge arms and two bridge diagonals, said bridge arms including said four branch circuits respectively, each connected-in at the said pair of carrier equipotential points, and said source of sig-

nal waves and said load circuit being connected respectively in said bridge diagonals.

2. A modulating system comprising sixteen rectifying elements arranged in groups, each group comprising four rectifying elements arranged in the form of a Wheatstone bridge, one diagonal of which bridge forms a ratio arm of a larger bridge including all sixteen rectifying elements, a multiwinding transformer, a carrier source connected through said transformer across the free diagonal of each of said smaller bridges, and a signal source and a load circuit connected in opposite diagonals of said larger bridge.

3. A system according to claim 2, in which the rectifying elements are individually so poled that the application of a carrier wave from the carrier source causes alternate pairs of opposite arms of the larger bridge to become conductive and causes the other two arms to be non-conductive while the first two are conductive.

4. A modulating system comprising a Wheatstone bridge network with the usual four corners, two diagonals, and four ratio arms, each ratio arm containing four rectifiers connected series-parallel, each parallel branch containing two rectifiers with their conductive directions opposed to each other, one parallel branch in each ratio arm comprising two rectifiers each with its conductive direction toward the nearest corner of the bridge, each remaining rectifier having its conductive direction away from its nearest bridge corner, a plurality of inductive windings, one in each bridge arm, each winding being connected between the inner junction of the rectifiers in one parallel branch and the inner junction of the rectifiers in the other parallel branch, a source of carrier waves inductively coupled with each of said windings, the poling of the windings being such that the carrier wave at any instant renders the rectifiers of two opposite bridge arms conductive and renders the remaining rectifiers non-conductive, and a signal source and a load circuit in opposite diagonals of the bridge.

5. A modulating system comprising a primary bridge network, a signal source and a load circuit connected in opposite diagonals of the network, a plurality of secondary bridges composed of rectifiers, means for connecting one secondary bridge in each arm of said primary bridge, a carrier source, a transformer coupling said carrier source to the secondary bridges and having a plurality of secondary windings, and means for so connecting the secondary windings that the rectifiers in one pair of opposite primary bridge arms are made conductive during one half-cycle of the carrier wave and the remaining rectifiers are made conductive during the succeeding half-cycle.

6. A modulating system comprising a primary bridge, a signal source in one diagonal of the bridge, a load circuit in the other diagonal of the bridge, a plurality of secondary bridge networks containing rectifiers, said secondary bridges being disposed one in each arm of the primary bridge, a carrier source, a transformer coupling said carrier source to said secondary bridges through a plurality of secondary windings, and means for connecting said secondary windings so that alternate pairs of primary bridge arms are rendered conducting successively in synchronism with the alternations of the carrier wave.

7. A modulating system comprising a primary bridge network each arm of which contains a secondary bridge composed of rectifiers, a signal source and a load circuit connected in opposite diagonals of the primary bridge, a carrier source, a multiwinding transformer coupling the carrier source to the secondary bridges, and means for connecting the windings of said transformer so that the phase of the carrier wave impressed upon one pair of opposite primary bridge arms is made opposite to the phase of the carrier wave impressed upon the other pair of primary bridge arms.

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