April 10, 1945. W. F. KANNENBERG 2,373,569

WAVE TRANSLATING SYSTEM

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FIG. 1.

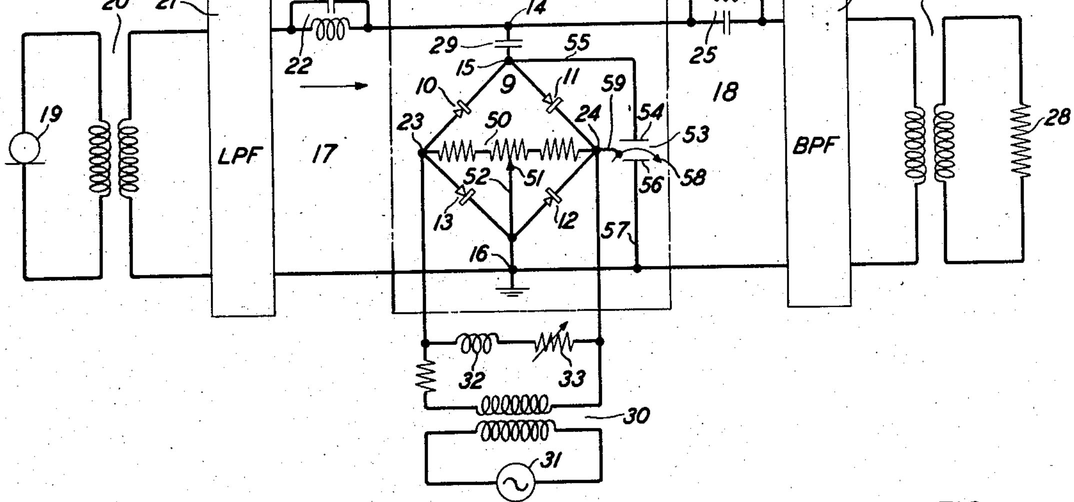


FIG. 2.

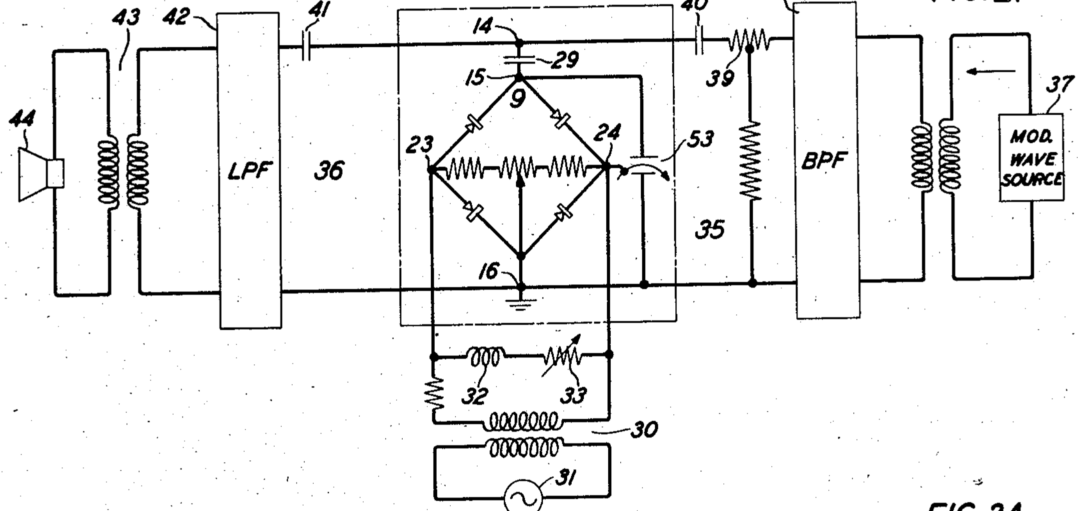


FIG. 3B.

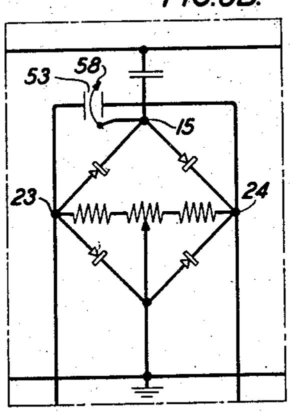

FIG. 3C.

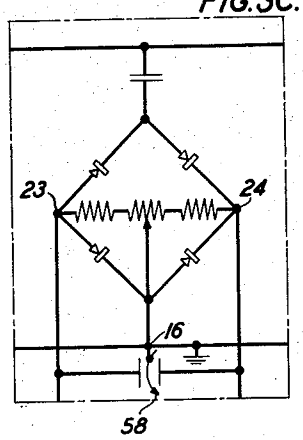

FIG. 3A.

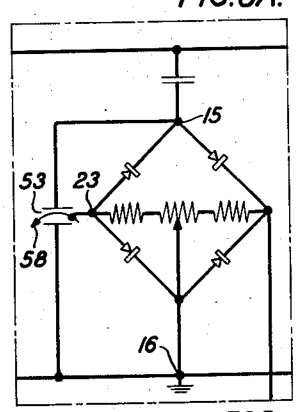

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FIG. 3D.

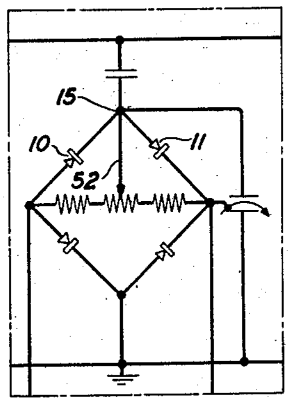



FIG. 3E.

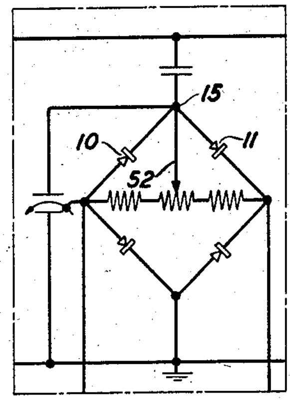



FIG. 3F.

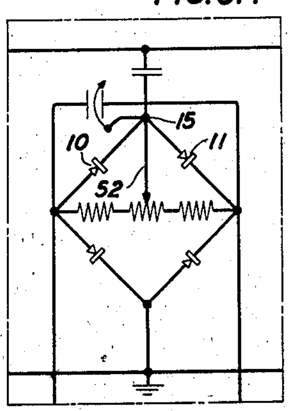
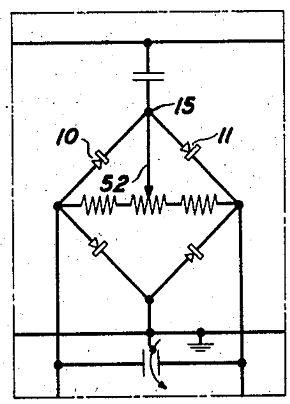



FIG. 3G.




14 FIG. 4.

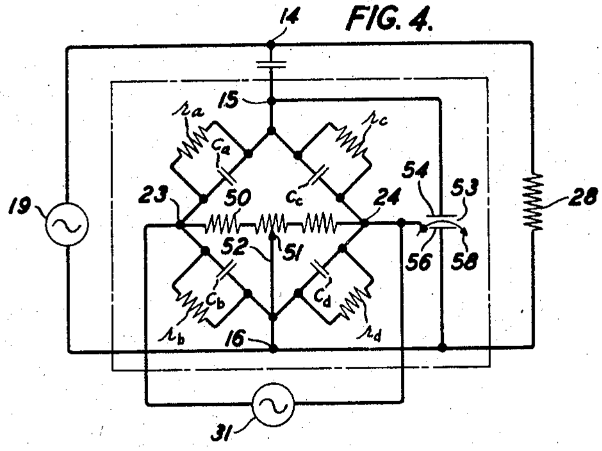



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FIG. 3H.

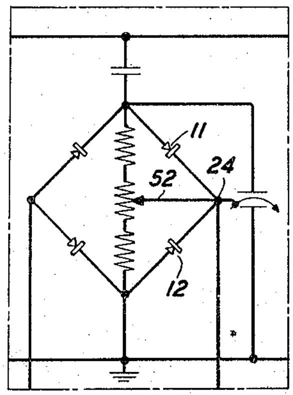



FIG. 3J.

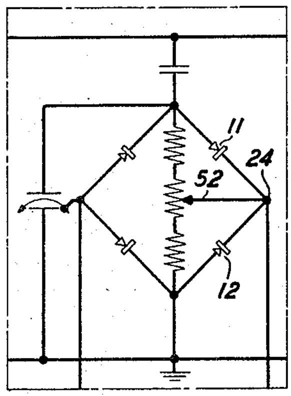



FIG. 3K.

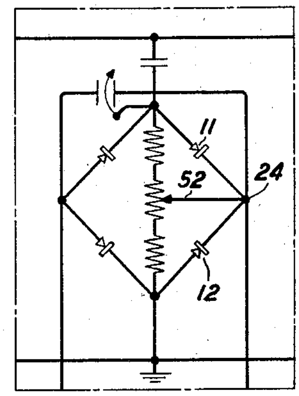



FIG. 3L.

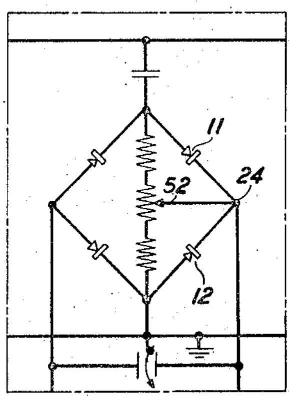



FIG. 3M.

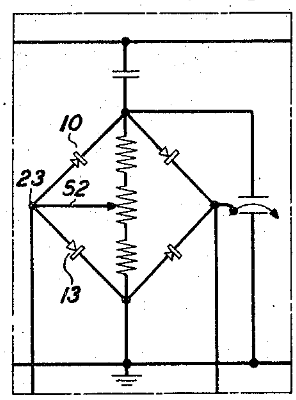



FIG. 3N.

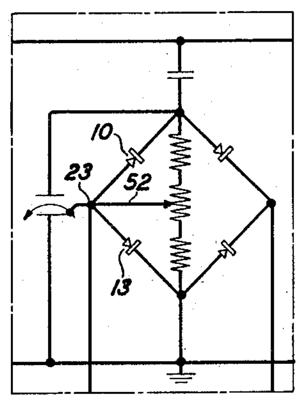



FIG. 3P.

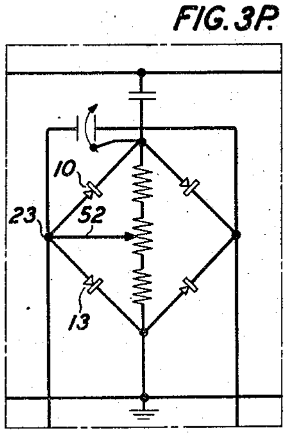
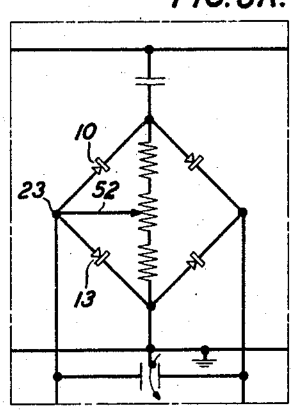



FIG. 3R.

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Patented Apr. 10, 1945 | 2,373,569

# UNITED STATES PATENT OFFICE

2,373,569

## WAVE TRANSLATING SYSTEM

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Application January 23, 1943, Serial No. 473,339

13 Claims. (Cl. 178—44)

This invention relates to frequency changers which may be either modulators, demodulators, or detectors used in intelligence transmission systems of the carrier current type, and more particularly to such frequency changers embodying non-linear resistance elements.

Non-linear resistance elements employed in bridge form in modulators, demodulators, and detectors offer the advantage that unmodulated carrier current can be suppressed in the output circuit without ancillary apparatus. Such carrier current suppression can be accomplished when the bridge is balanced. This means that the individual non-linear resistance elements should possess substantially identical characteristics. This is a difficult undertaking from a manufacturing standpoint, and ordinarily is incapable of achievement. Also, carrier suppression can be accomplished when one pair of bridge arms has a given characteristic while the other pair of bridge arms has a different characteristic, provided the placement of the bridge arms is such that the ratios of the bridge arms are substantially equal. This is usually difficult of attainment without considerable experimentation. In addition, carrier current suppression can be achieved with four bridge arms embodying dissimilar characteristics provided the effect of one type of dissimilarity counterbalances the effect of a different type of dissimilarity. This is only attainable by sheer accident.

In the absence of non-linear resistance elements possessing identical characteristics, carrier current suppression can be attained by controlling the ratios of the bridge arms such that the ratios are rendered substantially equal. This involves controlling the following three independent characteristics of the individual non-linear resistance element; namely, (1) resistivity during the forward current flow; (2) resistivity during the reverse current flow; and (3) capacity during the reverse current flow. In my Patent No. 2,271,078 granted January 27, 1942, one arrangement is disclosed for controlling the resistivity characteristic of the individual non-linear resistance elements during the forward current flow.

The present invention is concerned with frequency changers embodying arrangements for equalizing both the resistivity and capacity ratios of non-linear bridge arms during the reverse current flow.

The main object of the invention is to suppress unmodulated carrier current in the output circuit of a carrier current intelligence transmission system.

Another object is to equalize the resistivity ratio of the arms of a non-linear bridge during the reverse current flow.

A further object is to control the capacity ratio of the arms of a non-linear bridge during the reverse current flow.

In one type of familiar modulator and demodulator embodied in a carrier current intelligence transmission system, a plurality of non-linear resistance elements are arranged in the bridge form such that one diagonal is applied to both a source of modulating alternating current and a load circuit, and the opposite diagonal is connected to a source of carrier current. The bridge serves to translate the modulating and carrier currents into certain modulation components which are selected by the load circuit.

According to a specific embodiment of the present invention included in the above carrier current system, a resistor applied across one bridge diagonal has an adjustable contact extended to one terminal of the other bridge diagonal; and a double capacitor comprising a pair of stators and a rotor has both stators connected across a certain bridge diagonal and the rotor applied to one terminal of a different bridge diagonal. The resistor and lead associated therewith provide shunt paths around the non-linear elements of two adjacent arms whereby the resistivities of the elements in both latter arms are adjusted during the reverse current flow until the resistivity ratios of the bridge arms are substantially equal. The double capacitor also provides shunt paths around the non-linear elements of two further adjacent arms so that the capacities of the elements in both latter arms are adjusted during the reverse current flow until the capacity ratios of the bridge arms are substantially equal.

The invention will be readily understood from the following description when taken together with the accompanying drawings in which:

Fig. 1 is a schematic circuit diagram showing a specific embodiment of the invention used in the modulator of a carrier current intelligence transmission system;

Fig. 2 is a schematic circuit diagram showing the specific embodiment of the invention used in the demodulator of a carrier current intelligence transmission system;

Figs. 3A, 3B, 3C, 3D, 3E, 3F, 3G, 3H, 3J, 3K, 3L, 3M, 3N, 3P and 3R illustrate other embodiments of the invention which may be substituted in Figs. 1 and/or 2, and

Fig. 4 is a schematic circuit diagram showing a simplified form of the specific embodiment of the invention in Figs. 1 and 2.

The same reference numerals are employed to designate identical elements appearing in the several figures of the drawings.

Fig. 1 represents a modulating carrier current intelligence transmission system comprising a plurality of non-linear resistance elements 10, 11, 12 and 13 arranged in the form of a bridge 9 whose vertical diagonal 14, 15 and 16 are connected in shunt relation to an input circuit 17 and an output circuit 18. The input circuit 17 includes in sequence a source 19 of modulating alternating current waves, an input transformer 20, a low pass filter 21, and a tuned circuit 22 which is interposed in one side of this input circuit. The output circuit 18 embodies in sequence a tuned circuit 25 in one side thereof, a band-pass filter 26, an output transformer 27 and a load circuit 28. A capacitor 29 is interposed in the vertical bridge diagonal intermediate the terminals 14 and 15. Across the horizontal bridge diagonal 23 and 24 is applied the secondary winding of a carrier input transformer 30 whose primary winding is connected to a source 31 of alternating current carrier waves. Disposed in shunt of the secondary winding of the carrier input transformer is a serially connected inductance winding 32 and a variable resistor 33.

The operation of the modulating system of Fig. 1 is briefly that modulating waves from the source 19, carrier waves from the source 31 and bridge 9 serve to produce rectified current together with other modulation components which include waves whose frequencies extend over a certain range, and which are applied through the tuned circuit 25, band-pass filter 26, and output transformer 27 to the load 28. The tuned networks 22 and 25 and the serially connected inductance 32 and variable resistor 33 provide the bridge 9 with optimum terminating impedances which have substantially the most favorable magnitudes and frequency characteristics for transmitting the modulation components of all frequencies in the certain range with substantially maximum amplitudes.

The capacitor 29 interrupts the flow of rectified current from the bridge 9 to the input and output circuits 17 and 18, respectively. In addition, the polarity of the charge on the capacitor 29 tends to control the resistivities of the individual elements 10, 11, 12 and 13 during the forward current flow and thereby to equalize the flow of rectified current in the parallel bridge paths 23, 15 and 24 and 23, 16 and 24. This tends to bring the bridge 9 more nearly into balance for rectified current. As the alternating current resistivity characteristics of the individual non-linear elements tend to follow the rectified current resistivity characteristics during the forward current flow or conducting cycle, it is apparent that a corresponding improvement in the alternating current resistance balance of the bridge 9 is likewise accomplished. As the alternating current voltage is proportional to the effective resistance of the non-linear elements, it is evident that the alternating current difference of potential across the bridge diagonal 14, 15 and 16 substantially approaches zero. This tends to preclude a leak of the unmodulated waves from the carrier source 31 into the input and output circuits 17 and 18, respectively, during the forward current flow. A more complete description of the foregoing modulating system of Fig. 1 together with the operation thereof is contained in my patent, supra.

Fig. 2 represents a demodulating carrier current intelligence transmission system comprising the bridge 9 whose vertical diagonal 14, 15 and 16 is connected in shunt of input circuit 35 and output circuit 36. The input circuit 35 includes in sequence a source 37 of incoming modulated carrier waves, a band-pass filter 38, a resistance pad 39, and a capacitor 40 in one side; while the output circuit 36 embodies in sequence a capacitor 41 in one side, a low pass filter 42, an output transformer 43, and a wave translating apparatus 44. Across the horizontal diagonal of the bridge 9 are disposed in sequence the serially connected inductance 32 and variable resistance 33, carrier input transformer 30, and carrier source 31. Capacitor 29 is also connected in the vertical bridge diagonal.

The operation of the demodulating system of Fig. 2 is briefly that modulated carrier waves incoming from the source 37, carrier waves from the source 30 and the bridge 9 serve to produce rectified current and other modulation components which includes waves whose frequencies extend over a desired range which is equivalent substantially to that of the modulating waves supplied by the source 19, Fig. 1. Such modulation components are applied through the capacitor 41, low pass filter 42 and output transformer 43, to the translating apparatus 44. The serially connected inductance 32 and variable resistor 33, Fig. 2, pad 39, and capacitors 40 and 41 provide the bridge 9 with optimum terminating impedances which have substantially the most favorable magnitudes and frequency characteristics for transmitting to the translating apparatus 44 the modulation components of all frequencies in the desired range with substantially maximum amplitudes. In Fig. 2, the capacitor 29 serves to control the flow of rectified current in the bridge 9 so as to prevent a leak of unmodulated carrier from the source 31 into the input and output circuits 35 and 36, respectively, as previously explained with reference to Fig. 1. A more complete description of the demodulating system of Fig. 2 together with the operation thereof is contained in my patent, supra.

In accordance with the present invention as illustrated in Fig. 1, a resistor 50 disposed across the horizontal bridge diagonal 23, 24 embodies an adjustable tap 51 which is connected over lead 52 to bridge terminal 16. A double capacitor 53 is arranged such that stator 54 is applied over lead 55 to bridge terminal 15; stator 56 is connected over lead 57 to bridge terminal 16; and rotor 58 is connected over lead 59 to bridge terminal 24. This arrangement serves to balance the bridge 9 with reference to the resistivities and capacities of the individual unidirectional elements during the reverse current flow in a manner that will now be explained.

The individual non-linear elements during the reverse current flow are effectively individual R-C networks as illustrated in Fig. 4 which is essentially the system of Fig. 1 in simplified form. In order to obtain bridge balance in Figs. 1 and 4, it is necessary that the following ratios should obtain:

$$\frac{r_a}{r_b}=\frac{r_c}{r_d} \quad (1)$$

in which $r$ is resistivity, and

$$\frac{c_a}{c_b}=\frac{c_c}{c_d} \quad (2)$$

in which $c$ is capacity.

Let it be supposed that the effective value or $r_b$ is higher than that required to hold the ratio in Equation 1, and as a consequence the bridge, Fig. 4, is rendered unbalanced. The balanced condition can be restored to the bridge by arranging resistor 50, variable tap 51 and lead 52 in the manner hereinbefore explained in connection with Fig. 1. The tap 51 is actuated in the left-hand direction to decrease the magnitude of the resistance in shunt of the bridge arm 16, 23 in a path comprising bridge terminal 23, left-hand portion of resistor 50, tap 51, lead 52 and bridge terminal 16; and at the same time to increase the magnitude of the resistance in shunt of the bridge arm 16, 24 in a path comprising bridge terminal 24, right-hand portion of resistor 50, tap 51, lead 52 and bridge terminal 16. This means that the amounts of rectified current that would normally flow in the individual bridge arms 16, 23 and 16, 24 alone are now divided between the latter and the shunt paths associated therewith as previously traced.

As in the case of forward current flow in the non-linear elements pointed out above, the alternating and rectified current resistance characteristics of these elements tend to manifest similar trends. Hence, it has been found that changes of the rectified current characteristics in the direction of the reverse current flow due to a control of the magnitude of the rectified current tending to flow in the individual non-linear elements will cause corresponding changes in the alternating current resistance characteristics thereof. As mentioned in my patent, supra, substantially no rectified current difference of potential tends to exist across the bridge vertical diagonal 14, 15 and 16 when the individual non-linear elements possess substantially identical rectified current and voltage characteristics; and a rectified current difference of potential tends to exist across the bridge vertical diagonal when such characteristics are dissimilar.

Since the resistance of the shunt path associated with the bridge arm 16, 23 is decreased, then a decreased magnitude of rectified current is caused to flow in the latter arm; and since the resistance of the shunt path associated with the bridge arm 16, 24 is increased, then an increased amount of rectified current is caused to flow in the latter arm. Thus, the rectified current tends to decrease the magnitude of the effective value of the resistivity of bridge arm 16, 23 and to increase the magnitude of the effective value of the resistivity of bridge arm 16, 24. This causes the bridge balance of Equation 1 to be restored whereby a condition of no rectified current difference of potential is caused to be established across the bridge vertical diagonal 14, 15 and 16.

From the foregoing it is evident that as the alternating current resistance characteristics tend to follow closely the rectified current resistance characteristics of the non-linear elements in the reverse current flow, a corresponding improvement is effected in the alternating current resistance balance of the bridge. Since the alternating current voltage resistance of the non-linear elements is proportional to the resistivities thereof, as mentioned in my patent, supra, it is apparent that the alternating current difference of potential across the bridge diagonal 14, 15 and 16 approaches zero. This tends to diminish substantially, or to preclude entirely any leak of unmodulated carrier waves from the source 31 to the circuits connected to the bridge terminals 14 and 16, in so far as the relative resistivities of the non-linear elements during the reverse current flow is concerned. When the effective value of $r_a$ is higher than that required to hold the ratio in Equation 1, the latter may be restored by actuating the tap 51, Fig. 4, in the right-hand direction. In such case, the opposite action takes place with reference to the adjustment of the relative magnitudes of $r_b$ and $r_a$.

Let it be supposed that the effective value of $c_b$ is higher than that required to hold the ratio in Equation 2, and as a consequence the bridge, Fig. 4, is rendered unbalanced. A balanced condition can be restored by arranging the double capacitor 53 in the manner described previously concerning Fig. 1. The rotor 58, Fig. 4, is actuated such that its effective capacity with the stator 54 is decreased while at the same time its effective capacity with the stator 56 is increased. This means that the effective capacity of bridge arm 15, 24 is decreased and that of bridge arm 16, 24 is increased. So long as the alternating current potential characteristics of the individual non-linear elements are such that the ratio in Equation 2 obtains, then the alternating current difference of potential across the vertical bridge diagonal 14, 15 and 16 substantially approaches zero. This tends to diminish substantially, or to preclude entirely any leak of unmodulated carrier waves from the source 31 to the circuits connected to the bridge terminals 14 and 16, in so far as the relative capacities of the non-linear elements during the reverse current flow is concerned. When the effective value of $c_d$ is higher than that required to hold the ratio in Equation 2, the latter may be restored by actuating the rotor 58 in such direction as to decrease the effective capacity of the bridge arm 16, 24, and at the same time to increase the effective capacity of the bridge arm 15, 24. This likewise serves to establish a condition of balance in the bridge, Fig. 4, for the purpose just explained. Although Fig. 4 is mentioned as a simplified showing of the modulating system of Fig. 1, the former is also a similar showing of the bridge 9 of the demodulating system of Fig. 2.

The action described above regarding the operation of the bridge in Fig. 4 applies in a similar manner to the operation of bridge 9 in both Figs. 1 and 2 during the reverse current flow, with reference to both the resistivity and capacitive characteristics of the individual non-linear elements. Hence, substantially no leak of unmodulated carrier waves occurs from the carrier source 31 to the circuits connected to the vertical diagonal terminals 14 and 16 in Figs. 1 and 2. The foregoing action also pertains to Figs. 1 and 2 when the bridges of Figs. 3A, 3B, 3C, 3D, 3E, 3F, 3G, 3H, 3J, 3K, 3L, 3M, 3N, 3P and 3R are substituted therein, except in the respects that will be presently pointed out.

Fig. 3A shows a bridge which is similar to those of Figs. 1, 2 and 4 except the double capacitor 53 has its rotor 58 applied to the horizontal bridge terminal 23. Capacity adjustments are effected with reference to the non-linear elements in the bridge arms 15, 23 and 16, 23. Fig. 3B shows a bridge which is similar to those of Figs. 1, 2 and 4 except the double capacitor 53 has its rotor 58 connected to the vertical bridge terminal 15 and its stators 54 and 56 applied across the horizontal bridge diagonal. Capacity adjustments are accomplished with respect to non-linear elements in the bridge arms 15, 23 and 15, 24. Fig. 3C is similar to Fig. 3B except the rotor 58 is applied to the vertical bridge terminal 16 so that capacity adjustments are made concerning the non-linear elements in the bridge arms 16, 23 and 16, 24.

Fig. 3D shows a bridge which is similar to those in Figs. 1, 2 and 4 while Figs. 3E, 3F and 3G show bridges which are similar to those in Figs. 3A, 3B and 3C except in each of Figs. 3D, 3E, 3F and 3G the lead 52 is extended to the upper vertical bridge terminal 15. Resistivity adjustments are effected in each of Figs. 3D, 3E, 3F and 3G with reference to the non-linear elements 10 and 11.

Figs. 3H, 3J, 3K and 3L show bridges which are similar to those in Figs. 1, 2 and 4, and Figs. 3A, 3B and 3C, respectively, except the resistor 50 is disposed across the vertical diagonal of the bridge in each of the former figures and the lead 52 is extended to the horizontal bridge terminal 24. In Figs. 3H, 3J, 3K and 3L, resistivity adjustments are accomplished with reference to the non-linear elements 11 and 12. Figs. 3M, 3N, 3P and 3R illustrate bridges which are similar to those in Figs. 3H, 3J, 3K and 3L, respectively, except the lead 52 is extended to the horizontal bridge terminal 23. In Figs. 3M, 3N, 3P and 3R, resistivity adjustments are effected with respect to non-linear elements 10 and 13.

What is claimed is:

1. A wave translating system comprising a plurality of non-linear rectifier elements arranged in the form of a bridge, a plurality of circuits to supply alternating current waves to the diagonals of said bridge for translation into alternating current waves of certain frequency and rectified current, a load circuit to utilize said certain waves, means comprising a capacitor connected in series with one bridge diagonal to prevent a flow of said rectified current in circuits connected to said one bridge diagonal, means to establish shunt paths across each of two certain bridge arms for said rectified current comprising a resistor applied across a certain bridge diagonal and a lead extending from a preselected point on said resistor to one bridge terminal lying in the opposite bridge diagonal, and means to establish shunt paths across each of two certain bridge arms for waves flowing in said bridge comprising a double capacitor comprising a pair of stators and a rotor disposed across certain bridge terminals such that said stators are connected to terminals lying in a preselected bridge diagonal and said rotor is connected to a further terminal lying in a different bridge diagonal.

2. A wave translating system comprising a plurality of non-linear rectifier elements arranged in the form of a bridge, a plurality of circuits to supply alternating current waves to the diagonals of said bridge for translation into alternating current waves of certain frequency and rectified current, a load circuit to utilize said certain waves, and means to establish shunt paths for said rectified current across each of two certain bridge arms for balancing the resistivities of said elements during reverse current flow and thereby precluding a leak of waves from one circuit connected to one bridge diagonal into circuits connected to the other bridge diagonal, comprising a resistor applied across terminals lying in a certain bridge diagonal, and an electrical connection having one end attached to a further terminal lying in the opposite bridge diagonal and its other end adjustably attached to said resistor.

3. The wave translating system according to claim 2 in which said resistor is applied across terminals lying in the horizontal bridge diagonal, and said connection has said one end attached to said further terminal which lies in the vertical bridge diagonal.

4. The wave translating system according to claim 2 in which said resistor is applied across terminals lying in the horizontal bridge diagonal and said connection has said one end attached to said further terminal which constitutes the lower terminal of the vertical bridge diagonal.

5. The wave translating system according to claim 2 in which said resistor is applied across terminals lying in the vertical bridge diagonal, and said connection has said one end attached to said further terminal which lies in the horizontal bridge diagonal.

6. The wave translating system according to claim 2 in which said resistor is applied across terminals lying in the vertical bridge diagonal, and said connection has said one end attached to said further terminal which constitutes the left-hand terminal of the horizontal bridge diagonal.

7. A wave translating system comprising a plurality of non-linear rectifier elements arranged in the form of a bridge, a plurality of circuits to supply alternating current waves to the diagonals of said bridge for translation into alternating current waves of certain frequency, a load circuit to utilize said certain waves, and means to balance the capacities of said elements during reverse current flow thereby controlling the leak of waves from one circuit connected to one diagonal into circuits connected to the other bridge diagonal, comprising a double capacitor comprising a pair of stators and a rotor connected to certain bridge terminals such that said stators are connected to terminals lying in the same bridge diagonal and said rotor is applied to a further terminal lying in the opposite bridge diagonal.

8. The wave translating system according to claim 7 in which said stators are extended to terminals lying in the vertical bridge diagonal, and said rotor is applied to said further terminal which lies in the horizontal bridge diagonal.

9. The wave translating system according to claim 7 in which said stators are extended to terminals lying in the vertical bridge diagonal, and said rotor is applied to said further terminal which constitutes the right-hand terminal of the horizontal bridge diagonal.

10. The wave translating system according to claim 7 in which said stators are extended to terminals lying in the horizontal bridge diagonal, and said rotor is applied to a further terminal lying in the vertical bridge diagonal.

11. The wave translating system according to claim 7 in which said stators are extended to terminals lying in the horizontal bridge diagonal, and said rotor is applied to said further terminal which constitutes the lower terminal of the vertical bridge diagonal.

12. A wave translating system comprising a plurality of non-linear rectifier elements arranged in bridge form, a plurality of circuits to supply alternating current waves to the diagonals of said bridge for translation into alternating current waves and rectified current, a load circuit to utilize said certain waves, means to balance the resistivities of said elements during the reverse current flow thereby precluding a leak of waves from a circuit connected to one bridge diagonal to circuits connected to the other bridge diagonal, comprising a resistor applied across a certain bridge diagonal, and an adjustable connection extending from a preselected point on said resistor to one bridge terminal lying in a different bridge diagonal, and means to balance the effective capacities of said elements during

the reverse current flow for preventing a further leak of waves from said circuit connected to said one bridge diagonal into said circuits connected to said other bridge diagonal, comprising a double capacitor comprising a pair of stators and a rotor connected across certain bridge terminals such that said stators are connected to terminals lying in the same bridge diagonal and said rotor is applied to a terminal lying in the opposite bridge diagonal.

13. A wave translating system comprising a plurality of non-linear rectifier elements arranged in the form of a bridge, a plurality of circuits to supply alternating current waves to the diagonals of said bridge for translation into alternating current waves of certain frequency and rectified current, a load circuit to utilize said waves of the certain frequency, means to balance the resistivities of said elements during the forward current flow to preclude a leak of waves from a circuit connected to one bridge diagonal into circuits connected to the other bridge diagonal, comprising a reactive element connected in series with said one bridge diagonal to prevent a flow of said rectified current from said bridge to said circuits connected to said other bridge diagonal, means to balance the resistivities of said elements during the reverse current flow thereby precluding a further leak of the waves from said circuit connected to said one bridge diagonal into said circuits connected to said other bridge diagonal, comprising a resistor disposed across a certain bridge diagonal, and an adjustable connection extending from said resistor to a bridge terminal lying in a different bridge diagonal, and means to balance the capacities of said elements during the reverse current flow to preclude an additional leak of waves from said circuit connected to said one bridge diagonal into said circuits connected to said other bridge diagonal, comprising a double capacitor comprising a pair of stators and a rotor connected across certain bridge terminals such that said stators are applied to terminals lying in the same bridge diagonal and said rotor is connected to a terminal lying in the opposite bridge diagonal.

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