

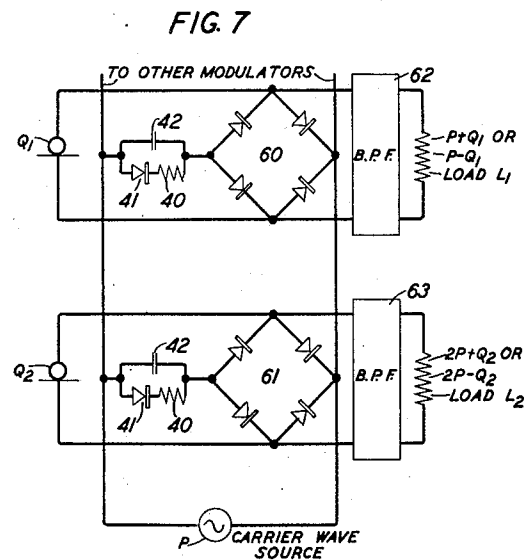
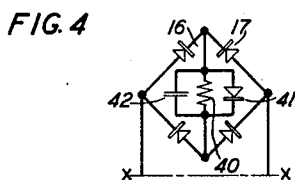
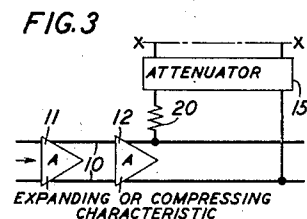
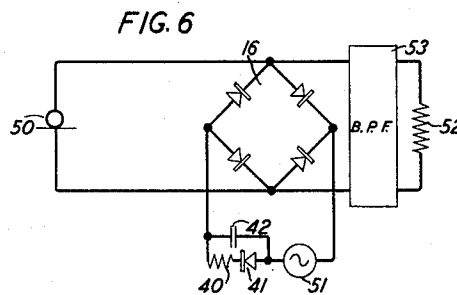
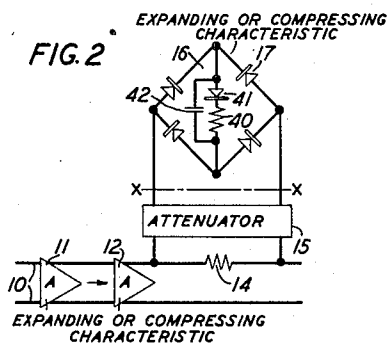
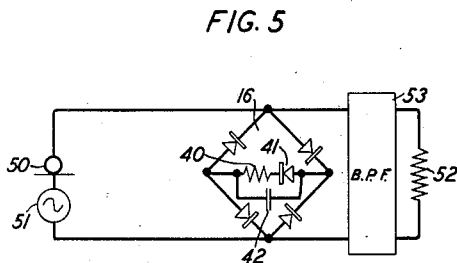
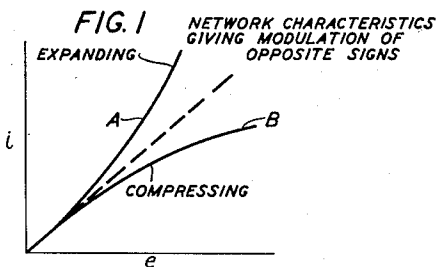
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2,293,628

MODULATING APPARATUS

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2,293,628

MODULATING APPARATUS

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11 Claims. (Cl. 178-44)

This invention relates to a signaling transmission system, and more particularly to a modulating arrangement to introduce into such system counter-distortion to compensate for the distortion generated by the components of the system such as one or more repeaters arranged in tandem.

In the copending application of E. Peterson, Serial No. 257,047, filed February 18, 1939, now Patent No. 2,233,061, issued February 25, 1941, an arrangement utilizing a non-linear resistance apparatus introduces into a repeater transmission system third order modulation products in phase opposition to third order modulation products generated by the repeaters so as to effect neutralization of the latter products. In order to obtain substantially maximum neutralization by such arrangement, it is necessary that the non-linear apparatus and repeaters follow substantially the same law of variation of the modulation products in response to varying amplitudes of applied signaling voltage. Accordingly, this invention contemplates a self-biasing modulating apparatus that follows a certain law of variation of the modulation products over a range of signaling voltage amplitudes.

It is a main object of the invention to control the law of variation of a non-linear apparatus embodied in a modulating system.

It is a further object to apply a varying self-biasing voltage to a non-linear resistance apparatus in response to varying amplitudes of input voltage.

It is another object to accomplish distortion compensation over a relatively extensive range of amplitudes of the input voltage.

It is a still further object to control the production of modulation products in carrier transmission systems.

It is still another object to provide different orders of modulation in a carrier transmission system embodying a common source of carrier waves.

As pointed out in the copending application of E. Peterson, supra, composite waves entering one or more repeaters in tandem in a transmission system will cause to occur in the output of each repeater, certain modulation products which will tend to accumulate from repeater to repeater. A non-linear modulating apparatus comprising preferably a plurality of non-linear resistance elements arranged in a bridge network and having one diagonal applied to the line at the output of a preselected repeater serves to effect neutralization of the accumulated modulation products

by introducing into the line at the output of the preselected repeater certain modulation products in phase opposition to the repeater produced modulation products.

In a preferred embodiment, this invention relates to a variably negative self-biasing arrangement applied to the other diagonal of the non-linear bridge network and comprising in series a resistor having a fixed resistance characteristic and a resistor having a non-linear resistance characteristic, and a capacitor applied in shunt of both latter resistors.

A feature of the invention is that the amplitude of the signaling voltage controls the variably negative self-biasing voltage so that a certain law of variation of the modulation products produced by the non-linear bridge network may be obtained over a range of amplitudes of signaling voltage. Such feature has a particular application in the distortion neutralization arrangement mentioned in the copending application of E. Peterson, supra. Another feature is that the non-linear bridge network may be expeditiously adapted to provide in carrier transmission systems certain orders of modulation. In the latter connection two or more non-linear bridges may be utilized with a common source of carrier waves to effect modulation products of different orders of modulation, each non-linear bridge being operatively associated with a suitably selective filter to transmit a certain order of modulated component to each discrete signaling channel.

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

Fig. 1 shows characteristic curves of current versus voltage for non-linear apparatus having either expanding or compressing characteristics;

Fig. 2 is a schematic diagram illustrating the preferred embodiment of the invention applied serially in a transmission line to neutralize repeater-produced distortion which may possess either an expanding or a compressing characteristic;

Fig. 3 is a modification of Fig. 2 illustrating the invention applied in shunt of the transmission line;

Fig. 4 is an alternate embodiment of the invention;

Fig. 5 is a schematic diagram delineating the invention in a system to combine signaling and carrier waves in certain desired components for selection by a load and in which the signaling and carrier sources and the load are connected in series;

Fig. 6 is a modification of Fig. 5 in which the signaling source and load are connected in series and the carrier source is applied in shunt of both thereof; and

Fig. 7 is a schematic diagram embodying an expansion of Fig. 6 to effect modulation products of different orders of modulation by using a common source of carrier waves.

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

Fig. 1 embodies curves having current and voltage plotted as the respective ordinate and abscissa of non-linear apparatus producing third order modulation products. Curve A is a plot of the equation $i = a_1e + a_3e^3$ which is characteristic of so-called expanding products. Curve B is a plot of the equation $i = a_1e - a_3e^3$ which is characteristic of so-called compressing products.

Fig. 2 shows a portion of a signaling transmission line 10 embodying in sequence repeaters 11 and 12 and transmitting in the direction indicated by the arrow. Inserted in series in one side of the line in the output of the repeater 12 is an impedance 14 which possesses such value of resistance as to cause relatively small line unbalance. Connected across the impedance 14 is an attenuator 15 which is applied to one diagonal of a non-linear bridge network 16 comprising a plurality of non-linear resistance elements 17. The repeaters 11 and 12 are each preferably a vacuum tube amplifier having either an expanding or compressing characteristic regarding the production of third order modulation products. As seen in Fig. 2, the non-linear network is effectively connected in series in the line and may possess either an expanding or compressing characteristic concerning the production of third order modulation products.

Assuming a composite wave of frequency components p and q impressed on the input of the line, then it may also be assumed that among other products the output of the repeater 12 contains the products p , q , and $2p - q$. These products will cause individual potential drops across the impedance 14 at the respective frequencies. Accordingly, current of the frequencies p , q and $2p - q$ will be caused to flow in the bridge network. From this it may be assumed that the output of the bridge network will chiefly include current of the components p , q , $2p - q$. The third order product $2p - q$ in the output of the bridge network is approximately 180 degrees out of phase with the third order product $2p - q$ in the output of the repeater 12, if the repeater 12 effects a compressing characteristic and the bridge network effects an expanding characteristic, or vice versa. Consequently, these discrete third order products will substantially neutralize each other, as the magnitude of output of the bridge network may be controlled by the attenuator 15. While the neutralization of only one specific third order modulation product is mentioned, it is to be understood that such neutralization may be accomplished by the single network 16 with regard to all third order modulation products. The products to be neutralized may be due to repeater 12, alone, or the accumulated products due to repeaters 11 and 12.

Fig. 3 shows a section of a signaling transmission line in which the non-linear network is effectively applied in shunt of the line. In this connection it is understood that the portion of Fig. 2 above the line X-X is to be included above

the line X-X of Fig. 3, and therefore the operation of Fig. 3 is substantially the same as that pointed out above for Fig. 2. Thus, the third order products effected by one or more repeaters are substantially neutralized by introducing into the output of the latter in phase opposition equivalent modulation products generated by the non-linear network.

A more complete description of the aforementioned action may be had by referring to the compending application of E. Peterson, supra.

In accordance with this invention, the amplitudes of the modulation products effected by the non-linear bridge network are controlled so as to be substantially identical with the amplitudes of the modulation products generated by the line repeaters over a range of amplitudes of input voltage in order to obtain substantially complete neutralization. In other words, such neutralization is efficiently accomplished when both the line repeaters and the non-linear bridge network follow substantially the same law of variation over the same range of amplitudes of input voltages. Such variation is assumed to be a cube law for the purpose of this illustration.

Consequently, this invention provides that the third order modulation products effected by the non-linear bridge network vary as the cube of the input voltages over a relatively large range of amplitudes of the latter. This law of variation is obtained by applying a variable negative self-bias to the discrete non-linear resistance elements of the bridge network in a manner that will be presently explained. Referring to Fig. 2, the diagonal of the bridge network opposite to that applied to the line embodies in series an element 40 having a fixed resistance characteristic and an element 41 having a non-linear resistance characteristic, and in shunt of both latter elements a capacitor 42.

An alternate embodiment of the invention shown in Fig. 4 comprises the resistors 40 and 41 and capacitor 42 applied in parallel to the opposite diagonal of the bridge network. In this connection it is to be understood that the circuit portion above the line X-X of Fig. 4 may be substituted for the circuit portion above the line X-X of Figs. 2 and 3.

The law of variation of the third order modulation products effected by the non-linear bridge network may be changed by adjusting the value of the fixed resistance 40 and the value of the non-linear resistance element 41. The function of the capacitor 42 is to short-circuit any alternating current so that the network comprising resistance elements 40 and 41 and the capacitor 42 responds only to direct current and therefore acts as a direct-current resistance. In this connection it is, of course, understood that the direct current is obtained by rectification of the signaling voltage. Thus, the network comprising the resistors 40 and 41 and capacitor 42 serves to apply a variable negative self-bias to the discrete non-linear elements in response to varying amplitudes of input voltage. An outstanding feature of this arrangement is that the use of the non-linear element 41 provides that the cube law of variation is effective over a relatively large range of amplitudes of input voltage.

While the above has been described with regard to the neutralization of repeater-produced distortion, it is to be understood that similar neutralization could be effected for distortion caused by other components of a signaling system.

The invention is also applicable to modulating

and demodulating systems to produce desired orders of modulation. Referring to Fig. 5 a signal source 50, a carrier source 51 and a load 52 are applied serially to the vertical diagonal of the non-linear bridge network 16. An output filter 53 interposed between the vertical diagonal of the bridge network 16 and the load 52 serves to select the desired modulated component. Referring to Fig. 6, the signal source and load are connected serially to the vertical diagonal of the bridge network while the carrier source is applied to the horizontal diagonal thereof. The self-biasing network comprising resistors 40 and 41 in series and capacitor 42 in shunt of both thereof as shown in Fig. 2 is applied directly to the horizontal diagonal of the non-linear bridge network 16 in Fig. 5, and to the same diagonal in series with the carrier source 51 in Fig. 6. In this connection it is to be understood that the self-biasing network may also comprise the resistors 40 and 41 and capacitor 42 in parallel as shown in Fig. 4 and this may also be employed in Figs. 5 and 6. In Figs. 5 and 6 the signal and carrier waves are combined in the well-known manner to produce a signal modulated carrier wave. For a more complete understanding of such action, reference is made to the patents of F. A. Cowan and R. S. Caruthers, Nos. 1,959,459 and 2,086,601, granted May 22, 1934, and July 13, 1937, respectively.

As previously pointed out in connection with this invention as shown in Figs. 2, 3 and 4 the law of variation of the modulation products effected by the non-linear bridge network may be changed by adjusting the value of the fixed resistance 40 and the value of the non-linear resistance 41, and thereby the value of the negative self-bias applied to the individual non-linear elements constituting the bridge network. Accordingly, the law of variation of the non-linear network to effect a desired modulated product for selection by the band filter 53, Figs. 5 and 6, is rendered effective by such negative self-bias over a relatively large range of signal-voltage amplitudes. The modulation accomplished by the arrangements of Figs. 5 and 6 is preferably described as third order, although second or other order may also be expeditiously achieved.

The invention is further applicable to produce different orders of modulation in the same carrier system. Referring to Fig. 7, which is an expansion of Fig. 6, a signal source Q_1 and load L_1 are applied in series to the vertical diagonal of a bridge network 60, and a signal source Q_2 and load L_2 are applied in series to the vertical diagonal of a bridge network 61. Across the horizontal diagonals of both bridge networks 60 and 61 is a common carrier wave source P. The self-biasing arrangement comprising the series resistors 40 and 41 shunting capacitor 42 as shown in Fig. 2 is applied to the horizontal diagonals of each of the bridge networks 60 and 61 in series effectively with the carrier source P, and is identical with the corresponding self-biasing arrangement applied to the horizontal diagonal of the bridge network 16 illustrated in Fig. 6. In this connection it is to be understood that the self-biasing arrangement comprising the resistors 40 and 41 and capacitor 42 in parallel may also be employed in Fig. 7.

In the operation of Fig. 7, the bridge network 60 is self-biased to produce second order modulation and the band-pass filter 62 is designed to select either the upper or lower side-band of the products $P \pm Q_1$, depending on the modulated

component to be transmitted to the load L_1 ; and the bridge network 61 is self-biased to effect third order modulation and the band-pass filter 63 is designed to select either the upper or lower side-band of the products $2P \pm Q_2$, depending on the modulated component to be transmitted to the load L_2 . It is to be understood that other orders of modulation may be accomplished by connecting additional signaling systems across the common carrier source P in the manner of the systems embodying signal source Q_1 and load L_1 and signal source Q_2 and load L_2 , respectively. A more complete understanding of the modulation action may be had by referring to the Cowan and Caruthers patents, supra.

A feature of the invention as applied to Figs. 5, 6 and 7 is that the amplitude of the signaling voltage so controls the variably negative self-biasing voltage that a certain law of variation of the modulation products effected by the non-linear bridges may be obtained over a range of amplitudes of signaling voltage. In other words, the desired modulated component may be obtained regardless of large variations of the amplitude of the signaling voltage.

What is claimed is:

1. In combination, a plurality of non-linear resistance elements arranged in the form of a bridge for effecting modulation products, means to apply complex waves to one diagonal of said bridge for translation into certain modulation products, and means comprising an impedance network having an effective non-linear characteristic and applied to the other diagonal of said bridge to bias the elements thereof with an effective negative direct potential, due to rectification of the complex waves by said bridge, such that the certain modulation products possess amplitudes controlled by a range of amplitudes of the complex waves.

2. In the combination according to claim 1 in which the impedance network comprises reactive and resistive elements, the resistive elements being of fixed and non-linear resistance characteristics.

3. In the combination according to claim 1 in which the impedance network comprises in series a resistive element having a fixed resistance characteristic and a resistive element having a non-linear resistance characteristic, and in shunt of both latter elements a capacitive element.

4. In the combination according to claim 1 in which the impedance network comprises in parallel a capacitor and two resistors, both latter being of fixed and non-linear resistance characteristics.

5. In combination, a transmission line for alternating current signaling waves, means embodied in said line for translating signaling waves into unwanted modulation products, and means for neutralizing said unwanted modulation products by introducing equivalent modulation products in the output of said first-mentioned means in phase opposition to said unwanted modulation products, said second-mentioned means comprising a plurality of non-linear resistance elements having a bridge configuration of which one diagonal is connected to said line in the output of said first-mentioned means to translate signaling waves in said line into neutralizing modulation products equivalent to said unwanted modulation products, and impedance means having a non-linear resistance characteristic and applied to the opposite diagonal of said bridge to bias said elements thereof with an effective negative

direct potential, due to rectification of said signaling waves by said bridge, such that the amplitudes of said equivalent neutralizing modulation products are substantially equal to the amplitudes of said unwanted modulation products over a range of amplitudes of said signaling waves, said impedance biasing means comprising reactive and resistive elements, the resistive elements having fixed and non-linear characteristics.

6. In combination, a transmission line for alternating current signaling waves, a plurality of discrete means embodied in said line and subject individually to the production of unwanted modulation products tending to accumulate from one discrete means to the others in response to signaling waves in said line, means comprising a plurality of non-linear resistance elements arranged in a bridge configuration to generate, in response to signaling waves in said line, neutralizing modulation products equivalent substantially to said unwanted modulation products, circuit means to apply one diagonal of said bridge to the output of one of said discrete means to interpose in the output of said one discrete means said equivalent neutralizing modulation products in phase opposition to said unwanted modulation products thereby neutralizing said latter products, and impedance means having a non-linear characteristic and applied to the other diagonal of said bridge to bias said elements thereof with an effective negative direct potential, due to rectification of said signaling waves by said bridge, such that the amplitudes of said equivalent neutralizing modulation products are substantially equal to the amplitudes of said unwanted modulation products over a range of amplitudes of said signaling waves, said impedance biasing means comprising a capacitor and resistors having fixed and non-linear resistance characteristics.

7. In combination, a transmission line for alternating current signaling waves, apparatus embodied in said line and producing unwanted modulation products in response to signaling waves in said line, and means for neutralizing said unwanted modulation products by introducing equivalent modulation products in the output of said apparatus in phase opposition to said unwanted modulation products, said means comprising a plurality of non-linear resistance elements arranged in the form of a bridge whose one diagonal is connected to said line in the output of said apparatus to produce, in response to signaling waves in said line, neutralizing modulation products equivalent substantially to said unwanted modulation products, and means to bias said elements of said bridge with an effective negative direct potential, due to rectification of said signaling waves by said bridge, such that the amplitudes of said equivalent neutralizing modulation products are substantially equal to the amplitudes of corresponding unwanted modulation products over a range of amplitudes of said signaling waves, said biasing means comprising a resistor having a fixed resistance characteristic and a resistor having a non-linear resistance characteristic, both of said resistors being applied in series to the other diagonal of said bridge, and a capacitor applied in shunt of both said resistors.

8. In combination, a transmission line for alternating current signaling waves, at least one repeater embodied in said line and subject to the production of unwanted modulation products in response to signaling waves therein, a plurality of non-linear resistance elements arranged in a bridge configuration to generate, in response

to signaling waves in said line, neutralizing modulation products equivalent substantially to said unwanted modulation products, circuit means to apply one diagonal of said bridge to the output of said repeater to interpose therein said equivalent neutralizing modulation products in phase opposition to said unwanted modulation products thereby neutralizing said latter products, and impedance means having a non-linear characteristic and applied to the other diagonal of said bridge to bias said elements thereof with an effective negative direct potential, due to rectification of said signaling waves by said bridge, such that the amplitudes of said equivalent neutralizing modulation products are substantially equal to the amplitudes of said unwanted modulation products over a range of amplitudes of said signaling waves, said impedance biasing means comprising in series a resistor having a fixed resistance characteristic and a resistor having a non-linear resistance characteristic, and in shunt of both said resistors a capacitor.

9. In combination, a transmission line for alternating current signaling waves, a plurality of repeaters embodied in said line and subject individually, in response to signaling waves in said line, to the production of unwanted modulation products tending to accumulate from repeater to repeater, a plurality of non-linear resistance elements arranged in the form of a bridge to generate, in response to signaling waves in said line, neutralizing modulation products equivalent substantially to said accumulated unwanted modulation products, circuit means to apply one diagonal of said bridge to the output of one of said repeaters to interpose in the output of said one repeater said equivalent neutralizing modulation products in phase opposition to said accumulated unwanted modulation products thereby neutralizing said unwanted modulation products in the output of said one repeater, and impedance means having a non-linear resistance characteristic and applied to the other diagonal of said bridge to bias said elements thereof with an effective negative direct potential, due to rectification of said signaling waves by said bridge, such that the amplitudes of said equivalent neutralizing modulation products are substantially equal to the amplitudes of corresponding unwanted modulation products over a range of amplitudes of said signaling waves, said impedance biasing means comprising in series a resistor having a fixed resistance characteristic and a resistor having a non-linear resistance characteristic, and in shunt of both said resistors a capacitor.

10. In combination, a transmission line for alternating current signaling waves, apparatus embodied in said line and producing unwanted modulation products in response to signaling waves in said line, and means for neutralizing said unwanted modulation products by introducing equivalent modulation products in the output of said apparatus in phase opposition to said unwanted modulation products, said means comprising a plurality of non-linear resistance elements arranged in the form of a bridge whose one diagonal is connected to said line in the output of said apparatus to produce, in response to signaling waves in said line, neutralizing modulation products equivalent to said unwanted modulation products, and impedance means having a non-linear characteristic and applied to the other diagonal of said bridge to bias said elements thereof with an effective negative di-

rect potential, due to rectification of signaling waves by said bridge, such that the amplitudes of said equivalent neutralizing modulation products are substantially equal to the amplitudes of corresponding unwanted modulation products over a range of amplitudes of said signaling waves, said impedance biasing means comprising in parallel a resistor having a fixed resistance characteristic, a resistor having a non-linear resistance characteristic, and a capacitor.

11. In combination, a transmission line for alternating current signaling waves, a plurality of repeaters embodied in said line and subject individually, in response to signaling waves in said line, to the production of unwanted modulation products tending to accumulate from repeater to repeater, means comprising a plurality of non-linear resistance elements arranged in a bridge configuration to generate, in response to signaling waves in said line, neutralizing modulation products equivalent substantially to said unwanted modulation products, circuit means to

5 apply one diagonal of said bridge to the output of one of said repeaters to interpose in the output of said one repeater said equivalent neutralizing modulation products in phase opposition to said accumulated unwanted modulation products thereby neutralizing said unwanted modulation products in the output of said one repeater, and impedance means having a non-linear resistance characteristic and applied to the other diagonal of said bridge to bias said elements thereof with an effective negative direct potential, due to rectification of said signaling waves by said bridge, such that the amplitudes of said equivalent neutralizing modulation products are substantially equal to the amplitudes of corresponding accumulated unwanted modulation products over a range of amplitudes of signaling waves, said biasing means comprising in parallel a resistor having a fixed resistance characteristic, a resistor having a non-linear resistance characteristic, and a capacitor.

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