

June 3, 1941.

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2,244,249

WAVE TRANSLATION SYSTEM

Filed April 26, 1939

3 Sheets-Sheet 1

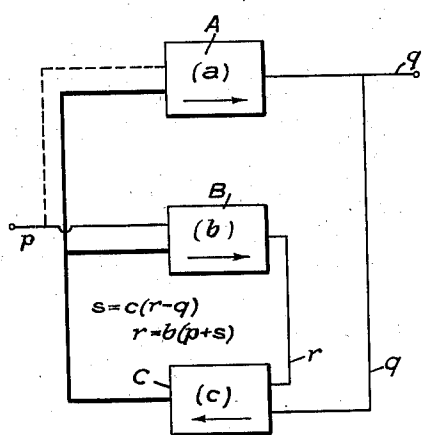


FIG. 1

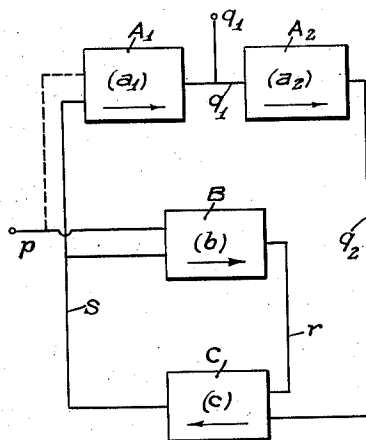


FIG. 2

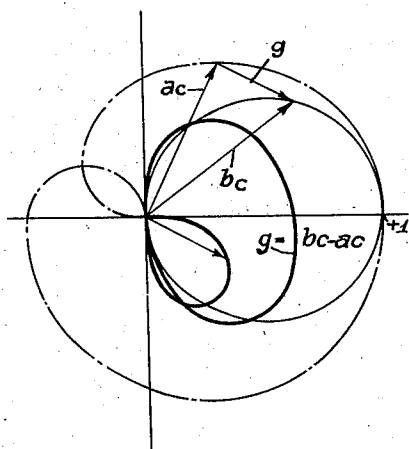
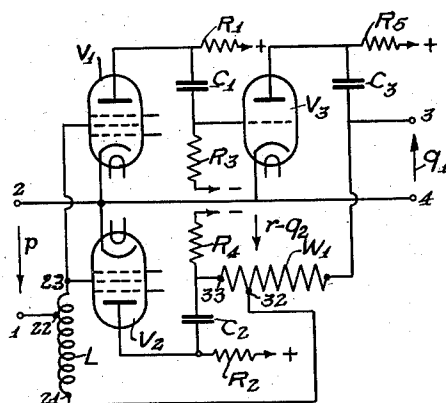


FIG. 3



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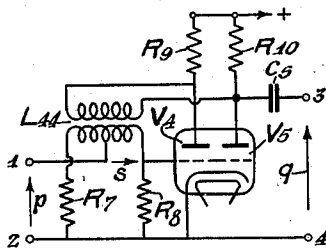


FIG. 5

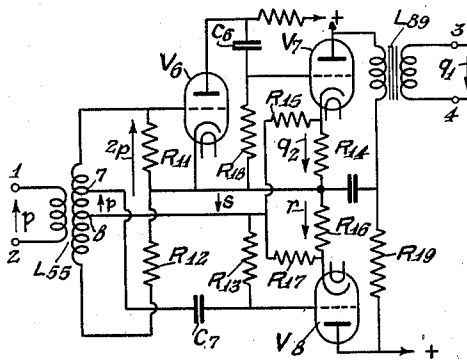


FIG. 6

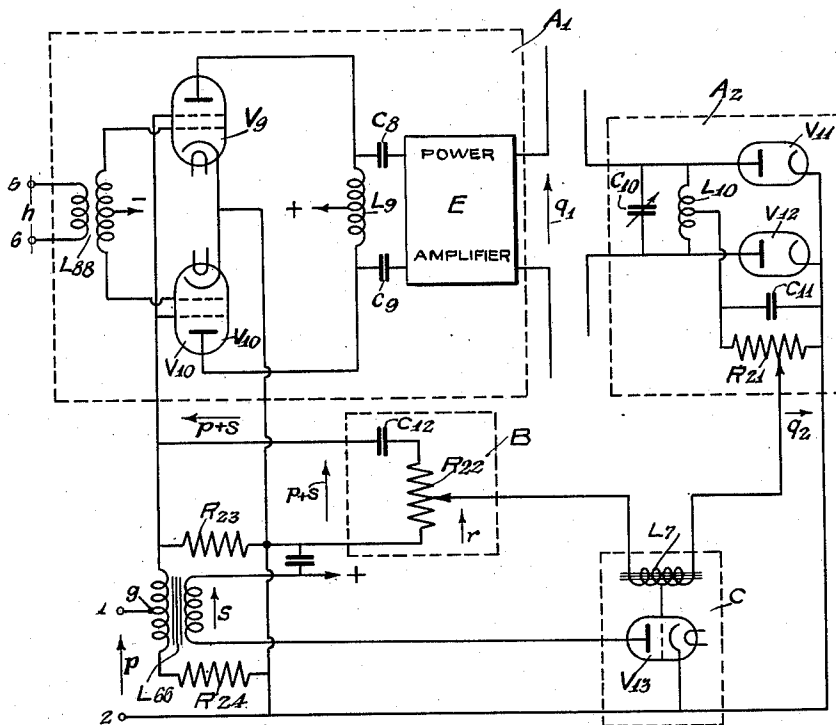


FIG. 7

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3 Sheets-Sheet 3

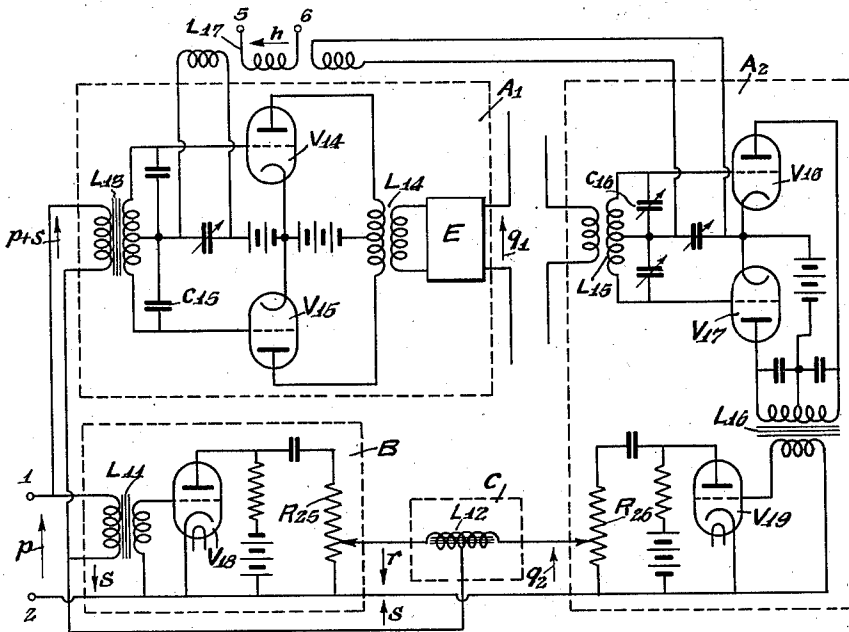


FIG. 8

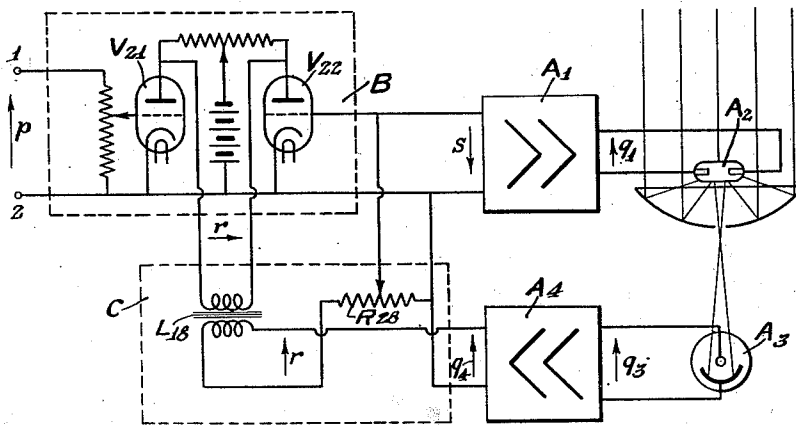


FIG. 9

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WAVE TRANSLATION SYSTEM

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In Switzerland December 31, 1938

17 Claims. (Cl. 179—171)

The present invention relates to improvements in feedback amplifiers and a method of operating the same and among the objects of the invention is to obtain and maintain a predetermined, such as a linear, input-output relationship in an electric translation or converting system.

It has already become known to maintain a linear relation between the input and output potentials of an electric amplifier serving for translating and/or converting variable signalling energy by the employment of inverse feedback or negative reaction, i. e., by feeding back a portion of the amplified output energy to the input of the system. Such feedback in inverse phase relation to the input energy entails a reduction of amplification or loss of signal strength which makes it necessary in most cases to employ one or more additional amplifying stages. Furthermore, the elimination or compensation of distortion in feedback amplifiers of the heretofore known type to secure a desired input-output relation enables the attainment of this object to a limited degree only as it is possible merely to reduce but never to completely eliminate the undesirable distortion. Moreover, the oscillations fed back due to undesirable phase shifts by the intercoupling networks in the main amplifying and feedback channels for selected frequencies or frequency bands may be increased in amplitude, thereby upsetting the operation and eventually resulting in self-excitation and substantial impairment of the operational stability of the feedback system. These and other reasons have made it impossible in the past to make full and efficient use of inverse feedback without the use of complicated and expensive circuit arrangements.

The above drawbacks and disadvantages are substantially overcome by the present invention. With this object in view the invention contemplates the provision of an auxiliary translation system or channel in addition to the main translation system to be controlled or corrected which auxiliary system has equal or approximately equal propagation characteristics to the main translation system. There is applied to this auxiliary system the potential to be translated, while a further correcting potential is impressed upon the input of both systems obtained by feeding back the difference of the output potentials of the systems through a suitable feedback channel or network. Due to the simultaneous impression of the correcting or feedback potential upon both systems, the new method will be designated as

"parallel inverse feedback" for the purpose of this specification.

An advantage of the novel method is the fact that distortions of the controlled system may be suppressed entirely thereby eliminating the possibility of building up of self-excited oscillations. Further aspects and advantages of the invention will become more apparent from the following detailed description taken with reference to the accompanying drawings illustrating several practical embodiments of the invention and wherein,

Figures 1 and 2 are block diagrams showing the general layout and organization of an inverse feedback system according to the invention,

Figure 3 shows a theoretical diagram explanatory of the function and operation of the invention,

Figures 4, 5 and 6 are simple amplifier circuits embodying improved inverse feedback according to the invention,

Figures 7 and 8 show embodiments of the invention as applied to a radio transmitter to compensate distortions of the signal modulation, and

Figure 9 illustrates the invention as applied to a light control arrangement for photographic recording or like purposes.

Referring to Figure 1, there are shown a translating or converting system A such as an amplifier, etc., a parallel or auxiliary translation system B provided according to the invention, and a feedback system or channel C. The propagation factors of the three systems; that is, the real or complex ratio, usually being dependent upon frequency, between the input and output potentials are designated by the characters a , b , c , respectively. The input magnitude or potential to be translated or converted without distortion by the entire arrangement is impressed at least upon the parallel system B or alternatively upon both the main translation system A and the parallel system B as shown in the drawings. The difference between the corrected output potential q of the system A and the output potential r of the auxiliary system B is applied to the feedback channel C resulting in a combined correcting potential s impressed both upon the main translation system A and the auxiliary or parallel system B.

As a result of the above connections, the output potential q may be expressed by the following equation:

$$q = a(np + s) + x \quad (1)$$

wherein x represents the distortion and interference potential produced in the system A.

The factor n is equal to 1 if the input potential p is applied to the system A and the system B with equal amplitude; in case of $m=n$, p is applied to A with m times the amplitude. If $n=0$, p is applied to the parallel system B only. The correcting potential s is obtained from the difference between the output potential ($r-q$) and in view of $r=b(p+s)$ is represented by the following expression:

$$s=c(r-q)=c(bp+bs-q)=\frac{bcp-cq}{1-bc} \quad (2)$$

by combining Equations 1 and 2 q is obtained as follows:

$$q=\frac{1}{1+d}[(b+and)p+dx] \quad (3)$$

wherein for the sake of abbreviation:

$$d=\frac{1-bc}{ac} \quad (4)$$

In order to suppress distortion the constants b and c of the auxiliary system and of the feedback system should be chosen in such a manner that their product is equal to unity; that is,

$$bc=1 \quad (5)$$

in which case d disappears. This condition can be fulfilled by providing at least one amplifier in the systems B or C serving to compensate the attenuation in the other system. In this case the output potential q is obtained as follows:

$$q=bp \quad (6)$$

From this latter expression it follows that the output potential q is free from all distortions and interference having its origin in the main translation system A and that its dependence upon the input potential p is determined solely by the propagation constant b of the auxiliary or parallel system B, while the propagation constant a of the system A which may be subject to substantial variations has no influence whatsoever upon the output potential.

The constants a , b , c may be chosen in such a manner that in addition to condition (5) approximately the following condition exists:

$$b=a \quad (7)$$

in which case a reduction of the amplitude of the output potential q compared with the output potential without feedback is avoided. An incorrect balance of the systems B and C whereby the factor d does not disappear entirely will only slightly affect the total propagation factor due to the denominator $(1+d)$ in Equation 3 and in view of the fact that in the equation the distortion appears multiplied with the factor d .

The relative distortion in the system A without feedback may be represented as follows:

$$y_0=\frac{x}{ap} \quad (8)$$

This distortion factor is reduced by employing parallel inverse feedback according to the invention as follows:

$$y_1=\frac{dx}{(b+and)p} \quad (9)$$

The reduction of the distortion is therefore represented by a relative distortion factor as follows:

$$z=\frac{y_1}{y_0}=\frac{ad}{(b+and)} \quad (10)$$

The latter, in case of fulfillment of Equation 7, corresponds approximately to the factor d . The

distortions may also be considerably reduced if condition (5) is not completely fulfilled. In general, the factor d may be kept very small whereby with sufficient approximation the output potential will be as follows:

$$q=bp+dx \quad (11)$$

In designing the system consideration should be given to the fact that the propagation characteristics in most cases are dependent upon frequency. The condition (5) should be fulfilled as far as possible for the frequency range of the distortions x to be suppressed. If only a single disturbing oscillation of definite frequency is to be suppressed it may suffice to comply with condition (5) for this frequency only. In many cases the oscillations to be transmitted and the distortions to be eliminated include a larger frequency range. A dependence of the factor b upon frequency which under circumstances cannot be avoided may be avoided at least partly by the design of the feedback circuit C to have a suitable frequency response as regards its propagation factor c to comply with condition (5) as far as possible.

From expressions 1, 2, 5 and 7 the output potential of the parallel system B is obtained as follows:

$$r=(2-n)bp-x \quad (12)$$

This potential is a minimum; that is, the power transmitted by the parallel system B is a minimum for $n=2$ i. e., by applying the input potential p to the system A to be corrected with an amplitude twice the value of the potential applied to the auxiliary system B. In this case $r=-x$ so that the potentials translated by B represent only the distortions, whereby not only the power but also the amplitudes in the parallel system B are small.

The correcting potential s considering Equations 6 and 12 may be expressed as follows:

$$s=c(r-q)=(1-n)bcp-cx \quad (13)$$

that is, the potential translated through the feedback system C is a minimum for $n=1$. Accordingly, the factor n representing the amplitude ratio between the components of the input potential p applied to the systems A and B, respectively, has a substantial influence upon the power or amplitudes in the systems B and C. By suitable choice of the factor n it is possible therefore to maintain the power of the parallel system B or the power in the feedback system at a low level to suit any existing conditions or requirements.

In practice at least one of the systems B and C should contain an amplifier. By the proper choice of the factor n the amplitudes within this amplifier may be maintained as small as possible.

The system A may consist of several individual sections in series or cascade such as shown in Figure 2 wherein the propagation constants of the systems A_1 and A_2 are designated by a_1 and a_2 , respectively and whereby the total propagation factor of the systems is represented as follows:

$$a=a_1a_2 \quad (14)$$

The output potential q_2 of A_2 is again determined by Equations 3, 6 and 11. If A_2 is a system free from distortion and interference, the output potential of A_1 taking into consideration Equations 6 and 5 will be as follows:

$$q_1=1/a_2q_2=b/a_2p \quad (15)$$

that is, the potential derived from the output of the system A_1 is independent of interference and distortion produced in this first translation system. The employment of the second system A_2 is advisable if the output potential of A_1 occurs in a form unsuited for combination with r or for the feedback through the system C. Thus, for instance, p , r , s and q_1 may be electric currents or potentials while q_2 may have the form of electro-magnetic or mechanical oscillatory energy converted into electric currents or potentials by the system A_2 .

The stability conditions of a system according to the invention are explained by reference to Figure 3. The propagation factors of the systems A, B, C are in general dependent upon frequency. The product $a.c$ of the constants of the systems A and C may be represented in a known manner by a vector whose point for variable frequencies describes a polar curve as shown in Figure 3, while at the same time the point of a further vector $b.c$ moves along a second curve. For the frequencies to be translated and especially the disturbing frequencies to be suppressed the vector $b.c$, in accordance with Equation 5, should coincide with the abscissa point +1 as nearly as possible. The same requirement applies to $a.c$, if Equation 7 is to be fulfilled. The difference vector $g=b.c-a.c$ also being dependent on frequency represents the total propagation factor of the entire system for a potential s from the input of the systems A and B to the output of the system C. Since the output of the latter is applied to both inputs through the feedback circuit building up of oscillations or self-excitation according to the investigations by Nyquist (see Bell System Technical Journal 1932, page 126 et seq.) is possible only if the polar curve g encloses the abscissa point +1.

From the foregoing it is seen that the factor g being the difference of two vectors whose absolute values are in most cases smaller than unity and may exceed unity only under the most unfavorable conditions may be kept within the admissible limits by most simple means to insure operational stability of the system. By adapting the phase shifting circuits in the system A to those of the system B it is furthermore possible to obtain a coincidence of the polar curves $a.c$ and $b.c$ to such an extent that g can never exceed the value 1. Inadmissible values of g may also be avoided in most cases by varying $a.c$ such as by adjusting the amplification or attenuation in the system A. The condition for avoiding self-excitation may therefore be maintained in the new system in a more simple and efficient manner than is possible in the known inverse feedback amplifier in which latter the product of the transmission factors of the main system and of the feedback system on the one hand should assume large negative values and on the other hand should not exceed unity.

As will be evident from the foregoing the new system is especially suited for suppression of interference and distortions in translating systems by employing a definite relation (Equation 5) between the propagation constants of the parallel and feedback systems, respectively. From Equation 3 it is seen that in case of negative values of the factor d , the polarity of the distortions will be reversed. Thus, for instance, for $d=-2$ there is obtained the following:

$$-q=(b-2an)p-2x \quad (16)$$

By an over-correction of this type of the distortion

in the individual translation systems it is possible to compensate the distortions in an associate non-corrected system.

Thus, in case of telephone lines with intermediate amplifiers a distortion $2x$ may be produced in two successive amplifier sections. In a third amplifier wherein the distortions are over-compensated with a factor $d=2$ there are thus produced distortions $-2x$, whereby the total distortion is eliminated by employing similar over-correction in every third line amplifier. This however presupposes that the effect of non-linear elements are equal in all amplifiers and that the distortions x are small compared with the signals being transmitted. In addition, the phase shifts in the individual amplifiers should be proportional to frequency to prevent a change of the signals by the line transmission excepting a delay and amplitude reduction in dependence upon frequency. When using a different degree of over-correction; that is, by selecting a different value of the factor d the requisite number of over-corrected amplifiers may be varied. A negative value of the factor d may be obtained while maintaining the stability conditions discussed with reference to Figure 3 in a simple manner by choosing the propagation constants a and b on the one hand and the propagation constant c on the other hand to be of definite polarity.

In Figures 4 to 9 there are shown several exemplifications of inverse feedback systems embodying the improvements according to the invention.

Referring to Figure 4, the system A_1 to be corrected comprises a two-stage amplifier including the electron amplifier valves V_1 , V_3 . The output of valve V_1 is impressed upon the input of the valve V_3 through a resistance coupling network of known construction comprising an anode or load resistance R_1 , coupling condenser C_1 , and a grid-leak resistance R_3 . The valve V_3 is connected to the output terminal 3 through a load resistance R_5 and a coupling condenser C_3 , the other output terminal 4 being connected to ground or cathode in a manner well known. The input potential p to be amplified is impressed across the terminals 1-2 through a portion of an inductance coil L simultaneously upon the input grid of the valve V_1 of the main amplifier system A_1 and upon the input grid of valve V_2 forming part of the auxiliary or parallel system B. The output of the valve V_2 is derived through a network comprising anode load resistance R_2 , a coupling condenser C_2 and a grid-leak resistance R_4 . By suitable design of R_2 , C_2 and R_4 , the propagation characteristics of the parallel system B may be adapted as far as required to the characteristics of the main amplifier A_1 thereby fulfilling the conditions for stability discussed with reference to Figure 3. The output terminals of the coupling condensers C_2 and C_3 in the auxiliary and main translation systems, respectively, are connected through a potential divider W_1 . A tap point on the latter is connected to the lower end of the induction coil L whereby the latter represents the feedback system C according to Figures 1 and 2. The tap 32 of the potential divider W_1 which latter corresponds to section A_2 in Figure 2 is chosen in such a manner that the amplified output potential q_1 provides a component q_2 of the potential derived from the tap 32 which component is approximately equal and opposite to the component r supplied at point 33 by the output of the auxiliary system B (valve V_2) thereby fulfilling the requirements according

to Equation 7. The feedback system C as pointed out is provided by the inductance L forming an auto-transformer for the potential $r-q_2$ to be impressed upon the inputs of the main and auxiliary translation systems. The ratio of trans-
 5 formation is adjusted by selecting the tap point 22 in such a manner that a definite potential variation at the control grid of valve V_2 will cause a like potential variation at the upper terminal
 23 of the induction coil L, thus fulfilling the requirements according to Equation 5. By neglecting a slight increase of the input potential p by the auto-transformer L, the output potential p_1 will be as expressed by Equation 15; that is, it will be independent of interfering potentials originating in and distortions produced by the amplifier V_1-V_3 .

In Figure 5, there is shown a modified amplifier employing parallel inverse feedback, wherein the parallel system B and the system A₁ to be corrected each consist of an amplifier valve unit V_4 and V_5 , respectively, arranged in a common envelope. The input potential p supplied at terminals 1-2 is impressed upon the control grid of both amplifying units through the center tap of the secondary of the feedback transformer L_{44} . The difference $r-q_1$ between the output potentials of both systems is applied to the primary of the transformer L_{44} constituting the feedback system, whereby the input or grid potential impressed upon both amplifiers is increased by an amount $s=c(r-q)$. R_9 and R_{10} are anode load impedances and C_5 is a coupling condenser for deriving amplified output potential.

There are further provided a pair of impedances R_7 and R_8 connected between the end of the primary of the transformer L_{44} on the one hand and between ground or cathode lead on the other hand. If these impedances are equal, a reaction of the fed back potential upon the preceding circuits connected to the terminals 1 and 2 is prevented. By equal design of both amplifier units V_4 and V_5 Condition 7 may be fulfilled. Condition 5 can be maintained by a suitable choice of the transformer L_{44} .

In the foregoing arrangement, the output potential q derived from a relatively large coupling condenser C_5 will be dependent on the input potential p as determined solely by the amplifying characteristics of the amplifier unit V_4 , independently of the load connected to the output terminals 3-4. This arrangement is therefore specially suited in all cases where constant voltage transmission conditions are required independently of load variations both with regard to amplitude and frequency of the load current.

In the circuits according to Figures 4 and 5 the input potential p is applied to the amplifier to be corrected and to the parallel system with equal amplitude; that is, the constant n according to Equations 3, 12 and 13 is equal to unity.

In Figure 6 there is shown an amplifying circuit wherein the input potential p is applied to the amplifier to be corrected with twice the amplitude; that is, with the factor $n=2$. There is applied through the transformer L_{55} a potential $2p$ to a two-stage amplifier comprising the valve V_6 and V_7 . The latter are connected through a resistance coupling network comprising a coupling condenser C_6 and a grid-leak resistance R_{18} . The output of valve V_7 is applied to the terminals 3-4 through an output or load transformer L_{59} . Input potential p derived from a tap point of the secondary of the transformer

L_{55} is simultaneously applied to the control grid of a further valve V_8 forming part of the auxiliary system through a coupling condenser C_7 and grid leak resistance R_{13} . Condenser C_7 and resistance R_{13} may be designed in such a manner as to adapt or balance any phase shifts produced by the coupling elements C_6 and R_{18} in the main amplifier to insure operational stability for extreme frequencies as discussed in connection with Figure 3. The anode of valve V_8 which is directly connected to the + pole of the high potential source is connected further to the ground or cathode end of the primary of the output transformer L_{59} through a resistance R_{19} . The cathode leads of valves V_7 and V_8 include resistances R_{14} and R_{16} , respectively, and there is connected to each of the cathodes a further resistance R_{15} and R_{17} , respectively. The open terminals of the last mentioned resistances are led to a common junction and the latter is connected to the center tap 8 of the secondary of the input transformer L_{55} . The cathode lead of the valves V_6 , V_7 , V_8 are returned to the junction of a pair of equal resistances R_{11} and R_{12} connected in series and across the secondary of the input transformer L_{55} .

There is developed by the cathode resistance R_{15} of valve V_8 a potential drop r corresponding approximately to the grid potential. A further potential drop being proportional to the output potential q_1 is developed by the cathode resistance R_{14} of the valve V_7 . The resistance R_{18} is large compared with the resistance R_{17} whereby there is produced at the junction between these resistances a feedback potential $s=c(r-q_2)$ wherein $c=1$ and $q_2=q_1$. This feedback potential is applied through the center tap 8 of the transformer secondary L_{55} to the valve V_6 on the one hand and to the valve V_8 on the other hand. The resistances R_{11} and R_{12} serve to maintain symmetrical conditions to prevent reaction of the fed back potential upon the circuits connected to the input terminals 1-2. Due to the fact that $n=2$, the amplitudes in the parallel system according to Equation 12 are at a minimum, whereby an effective equalization or elimination of distortion is ensured when using a valve V_8 with a non-linear operating characteristic. In contrast to the circuits shown in Figures 4 and 5, the circuit according to Figure 6 functions by current control by maintaining a definite ratio between the input potential and the output current independently of the load connected to the terminals 3-4.

Referring to Figure 7, there is shown an exemplification of the invention as embodied in a radio transmitter for preventing distortion of the signal modulation. The transmitter representing the system A₁ includes a push-pull modulator stage comprising a pair of electron valves V_9 and V_{10} having applied thereto the high frequency carrier h from a suitable source across input terminals 5-6 and through a coupling transformer L_{55} . The amplitudes of the high frequency carrier oscillations are modulated in accordance with the low frequency control potential $(p+s)$ impressed upon a different grid electrode of both valves V_9 and V_{10} . L_6 represents a common inductive load inductance connecting the anodes of the valves V_9 , V_{10} and having its center tap connected to the + pole of a high potential source in a manner well known in the art. The amplitude modulated carrier oscillations are fed through coupling condensers C_8 and C_9 to a high frequency amplifier E and

serve to energize an antenna for radiation in the form of an electro-magnetic wave having instantaneous amplitudes varying according to the potential or any other magnitude q_1 .

A small fraction of the radiated energy is absorbed by an auxiliary receiver constituting the system A_2 and including a tunable circuit comprised of an inductance coil L_{10} shunted by a condenser C_{10} . The received oscillations are rectified such as by a pair of diode rectifiers V_{11} and V_{12} and the rectified potential derived from the diode load resistance R_{21} shunted by a condenser C_{11} in accordance with well known practice. In this manner, a low frequency potential of desired amplitude $q_2 = a_2 q_1$ derived from a suitable tap point of the resistance R_{21} is obtained varying in proportion to the instantaneous amplitude of the high frequency oscillations q_1 . The low frequency potential $p+s$ besides being applied to the transmitter is simultaneously impressed upon the auxiliary system or network B whose propagation characteristics may be adapted by special means such as a series capacity C_{12} and shunt resistance R_{22} shown to the characteristics of the main translation channel comprising the systems A_1 and A_2 . The tap point on the diode load resistor R_{21} is connected to a suitable tap point of the resistance R_{22} through an impedance such as a choke coil L_7 , the center tap of which is connected to the control grid of an electron valve V_{13} constituting part of the feedback system C. In this manner there is produced in the output of valve V_{13} a feedback potential $s = c \cdot (r - q_2)$. The input potential p supplied at terminals 1—2 is impressed upon the transformer L_{25} through the center tap 9 and together with the feedback potential s supplied through the secondary of the transformer L_{25} results in a corrected input potential $p+s$ developed by the resistance R_{23} and applied both to the transmitter A_1 and to the auxiliary system B. The lower end of the primary of the transformer L_{25} is connected to the input terminal 2 through a compensating resistance R_{24} . If both resistances R_{23} and R_{24} are of equal value, reaction of the fed back energy upon the preceding circuits connected to the terminals 1—2 is prevented. By adjusting the potentiometer R_{22} in the auxiliary system B it is possible to vary the propagation factor b to fulfill the requirements according to Equation 5. As is understood from Equation 16 an arrangement of the type described which substantially corresponds to the principle circuit according to Figure 2 will result in a complete compensation or elimination of inherent distortions of the transmitter A_1 provided no additional distortions are produced in the receiver A_2 .

By means of the potentiometer R_{21} in the receiver A_2 , the propagation factor a_2 and as a result the output amplitude q_1 of the transmitter A_1 may be adjusted as follows from Equation 15. For a definite adjustment of R_{21} a will be equal to $a_1 \cdot a_2 = b$; that is, the output amplitude q_1 will be equal to the amplitude of a transmitter without correction or equalization.

Referring to Figure 8, there is shown an arrangement similar to Figure 7 but operating with suppression of the carrier and equalization of distortions by inverse feedback in accordance with the invention. The high frequency carrier oscillation h is applied to the balanced modulator comprising valves V_{14} and V_{15} through a transformer L_{17} . If the grid potentials are equal the high frequency potential induced in the output

transformer L_{14} will disappear and if the valves have non-linear operating characteristics the induced high frequency potential will vary in accordance with the low frequency potential impressed upon the grids in opposite phase through the modulating transformer L_{13} . The high frequency signal with suppressed carrier is amplified in E and radiated in the form of an electro-magnetic wave q_1 similar as in the preceding figure. The receiver A_2 comprises a balanced demodulator controlled by an auxiliary carrier h supplied from the transformer L_{17} . The input transformer L_{15} of the balanced modulator has its secondary terminals connected each to one of the grids of the modulating valves, the center tap of the transformer secondary being connected to the cathodes in a manner well known. There is thus produced between the anodes of the valves V_{16} , V_{17} a low frequency potential varying in proportion to the instantaneous amplitudes of the high frequency potential q_1 both in sign and magnitude. This low frequency potential is transmitted through the transformer L_{18} , amplifier V_{19} to voltage divider R_{26} to serve as control potential q_2 of the auxiliary receiver A_2 applied to the feedback system C. The latter contrary to the preceding figure contains no amplifier. On the other hand, an amplifier V_{18} is provided in the auxiliary system B controlled by an input transformer L_{11} having its primary connected in series with the input terminals 1—2 and a portion of an impedance L_{12} in the feedback system C and a portion of the output resistance R_{25} of the valve V_{18} . The other end of the induction coil L_{12} is connected to a tap of the voltage divider R_{26} . The feedback potential s derived from the tap of the induction coil L_{12} is thus applied together with the input potential p to both the input transformers L_{11} and L_{13} of the auxiliary system B and of the transmitter A_1 . As a result, distortions occurring in the transmitter are equalized in a manner understood from the foregoing.

In Figure 9 there is shown an embodiment of the invention for controlling the intensity of a beam of light in accordance with a low frequency magnitude or potential for use in photographic sound recording or like arrangements. The arrangement shown comprises an electrically controlled light source A_2 forming the system to be corrected which may be a gas discharge lamp of known construction. The intensity q_2 of the light flux radiated by the source A_2 varies in accordance with the output potential q_1 of the amplifier A_1 supplying control energy to the device A_2 . A_3 is a photo-electric cell receiving a small portion of the light flux radiated and serving to convert the received light into a corresponding electrical potential q_3 which is amplified by means of an amplifier A_4 to obtain an amplified potential q_4 impressed upon the feedback system C. The parallel system in the example shown comprises a pair of amplifying valves V_{21} and V_{22} for amplifying, respectively, the input potential p and the correcting potential s in such a manner as to obtain a differential potential $r = b(p+s)$ between the anodes of the valves. The differential potential is applied through a transformer L_{16} to the voltage divider R_{23} in the feedback system C. From the latter there is derived the correcting potential $s = c(r - q_4)$ by suitable tapping which potential is in turn applied to the input of the amplifier A_1 and of the parallel resistance B in a manner readily understood from the fore-

going. Since the input potential p is only impressed upon the parallel system p , the factor n in Equations 1, 3, 10, 12, 13 is equal to zero. By complying with the condition according to Equation 5 it is seen from Equation 3 that in an arrangement of this type a required relation between the input potential p and the output potential q_4 of the entire translation system $A_1-A_2-A_3-A_4$ may be obtained. If the systems A_3 and A_4 operate without distortion, there is furthermore obtained a desired relationship between the input potential p and the light flux q_2 ; that is, all distortions of and interference produced in the amplifiers A_1 and the light source are eliminated.

In the arrangements described a special adjustment of the parallel system B and of the feedback system C is required to fulfill the condition (5) in order to insure an efficient distortion elimination. This adjustment may be effected in an easy manner by increasing the factor b or c with the rest of the circuit being disconnected by increasing the amplification or decreasing the attenuation to a point where self-excitation sets in. Sure self-excitation by feedback is possible only if bc exceeds unity value, it is understood that the condition according to Equation 5 is just fulfilled at the point of starting of the oscillations. If then the potential is applied, the oscillations will again disappear, as this potential opposes the control potential r .

If the propagation factors of the several systems are adjustable by the provision of special regulating organs, the conditions according to Equation 5 and/or 7 or any other condition may be automatically maintained by an operative mechanical connection between the regulating organs independently of the adjustment made. In order to prevent undesired variations of the propagation characteristic of the parallel and feedback systems due to fluctuation of the constants of the amplifiers embodied in these systems, these amplifiers may be individually corrected to have linear input-output relation by means of any of the known means.

As will be evident from the foregoing the invention is not limited to the specific arrangement as shown and described for illustration, but that the underlying principle and concept disclosed are susceptible of numerous variations and embodiments differing from the exemplification shown herein and coming within the broad scope and spirit of the invention as defined in the appended claims. Thus, the invention is not to be interpreted limitatively as applying to electric wave energy only but may be employed with equal advantage in connection with arrangements for translating and converting other forms of oscillatory or vibratory energy such as sounds, mechanical vibrations, etc. The specification and drawings are accordingly to be regarded in an illustrative rather than a limiting sense.

I claim:

1. In a wave translation system, a main wave path and an auxiliary wave path, means for impressing wave energy to be translated upon at least the input of said auxiliary wave path, a load circuit connected to the output of said main wave path, means for combining a portion of the energy of said load circuit in inverse phase with the output energy of said auxiliary wave path to produce differential wave energy, a feedback path, means for impressing said differential energy upon the input of said feedback path, and

further means for impressing the output energy of said feedback path upon the inputs of both said main and auxiliary wave paths.

2. In a wave translation system, a main wave path and an auxiliary wave path, means for impressing wave energy to be translated upon at least the input of said auxiliary wave path, a load circuit connected to the output of said main wave path, means for combining a portion of the energy of said load circuit in inverse phase with the output energy of said auxiliary wave path to produce differential wave energy, a feedback path, means for impressing said differential energy upon the input of said feedback path, and further means for impressing the output energy of said feedback path upon the inputs of both said main and auxiliary wave paths, the product of the propagation constants of said auxiliary and feedback paths being substantially equal to unity.

3. In a wave translation system, a main transmission channel, an auxiliary transmission channel, means for impressing input wave energy upon at least said auxiliary transmission channel, the propagation constant of said auxiliary transmission channel being equal to the propagation constant of said main transmission channel, further means for combining output energies of said channels in inverse phase relation, a feedback channel for impressing the combined energy simultaneously upon the inputs of both said main auxiliary transmission channels, and a utilization circuit coupled to the output of said main transmission channel.

4. In a wave translation system, a main wave path and an auxiliary wave path, means for impressing wave energy to be translated upon the inputs of both said wave paths in predetermined amplitude ratio, a load circuit connected to the output of said main wave path, means for combining a portion of the energy of said load circuit in inverse phase with the output energy of said auxiliary wave path to produce differential wave energy, a feedback path, means for impressing said differential energy upon the input of said feedback path, and further means for impressing the output energy of said feedback path upon the inputs of both said main and auxiliary wave paths.

5. In a wave translation system, a main wave path and an auxiliary wave path, means for impressing wave energy to be translated with equal amplitude upon the inputs of both said wave paths, a load circuit connected to the output of said main wave path, means for combining a portion of the energy of said load circuit in inverse phase with the output energy of said auxiliary wave path to produce differential wave energy, a feedback path, means for impressing said differential energy upon the input of said feedback path, and further means for impressing the output energy of said feedback path upon the inputs of both said main and auxiliary wave paths.

6. In a wave translation system, a main transmission channel, an auxiliary transmission channel, means for impressing input wave energy simultaneously upon both said channels, the energy impressed upon said main transmission channel having twice the amplitude of the energy impressed upon said auxiliary transmission channel, further means for combining output energies of said channels in inverse phase relation, a feedback channel for impressing the combined energy upon the inputs of both said main and

auxiliary transmission channels, and a utilization circuit coupled to the output of said main transmission channel.

7. In a wave translation system, a main wave path and a first auxiliary wave path, means for impressing wave energy to be translated upon at least said auxiliary wave path, load means connected to the output of said main wave path, means for combining a portion of the load energy in inverse phase with the output energy of said auxiliary wave path to produce differential wave energy, a further auxiliary wave path, means for impressing said differential energy upon the input of said further auxiliary wave path, further means for impressing the output of said further auxiliary wave path upon the inputs of both said main and auxiliary wave paths, and an amplifier included in at least one of said auxiliary wave paths, whereby the gain of one auxiliary wave path is substantially equal to the attenuation of the other auxiliary wave path.

8. In a wave translation system, a main transmission channel subject to distortion, an auxiliary transmission channel having a substantial distortionless input-output characteristic, means for impressing input wave energy upon at least said auxiliary channel, further means for differentially combining output energies of said main and auxiliary transmission channels, a distortion-free feedback channel with means for applying the combined differential energy to the input thereof, means for applying the output of said feedback channel to the inputs of both said main and auxiliary transmission channels, and a utilization circuit connected to the output of said main transmission channel.

9. A wave translation system as claimed in claim 8 wherein the propagation constants of said main and auxiliary transmission channels on the one hand and of said feedback channel on the other hand are of opposite polarity to obtain a desired over-compensation of the distortion component produced by said main transmission channel.

10. A wave translation system as claimed in claim 8 wherein input energy is impressed simultaneously upon both said main and auxiliary channels.

11. A wave translation system as claimed in claim 8 wherein input energy is impressed simultaneously upon said main and auxiliary transmission channels with an amplitude ratio of 2:1 and wherein both channels have equal propagation constants.

12. A wave translation system as claimed in claim 8 including phase shifting means in said auxiliary channel to equalize its phase characteristic with that of said main transmission channel.

13. In a wave translating system, a main translation channel subject to distortion and adapted to convert electrical input energy into corresponding output energy of different character, a distortion-free pick-up system for re-converting a portion of the output energy of said translation channel into corresponding electrical energy, a distortion-free auxiliary transmission channel, means for applying electrical input energy to at least said auxiliary transmission channel, means for differentially combining the out-

put energies of said pick-up system and said auxiliary transmission channel, a distortion-free feedback channel with means for impressing thereon the combined differential energy, and means for applying the output of said feedback channel to the inputs of both said main translation and auxiliary transmission channels, said auxiliary channel and said feedback channel having propagation constants the product of which is substantially equal to unity.

14. In a wave translation system, a main amplifier subject to distortion, a converting device fed by the output of said amplifier for converting the electrical energy into energy of different character, a distortion-free pick-up system for re-converting a portion of the converted energy into corresponding electric energy, a distortion-free auxiliary amplifier, means for applying input energy to be converted to at least said auxiliary amplifier, further means for differentially combining the output energies of said pick-up system and said auxiliary amplifier, a distortion-free feedback channel with means for impressing thereon the combined differential energy, said auxiliary amplifier and said feedback channel having propagation constants the product of which is equal to unity, and means for applying the outputs of said feedback channel to the inputs of both said main and auxiliary amplifiers.

15. In a wave translation system as claimed in claim 13 wherein said main and auxiliary amplifiers possess equal gain and frequency characteristics.

16. In a wave translation system, a main transmission channel having imperfect transmission properties, an auxiliary transmission channel having substantially perfect transmission properties, means for impressing wave energy upon the input of at least said auxiliary transmission channel, a feedback channel having substantially perfect transmission properties, a load circuit coupled to the output of said main transmission channel, means for differentially combining a portion of the energy in said load circuit with the output energy of said auxiliary transmission channel, means for impressing the combined differential energy upon the input of said feedback channel, and further means for impressing the output of said feedback channel upon the input of both said main and auxiliary transmission channels.

17. In a wave translation system, a main transmission channel having imperfect transmission properties, an auxiliary transmission channel having substantially perfect transmission properties, means for impressing input wave energy simultaneously upon both said channels in predetermined amplitude relation, a feedback channel having substantially perfect transmission properties, a load circuit coupled to the output of said main transmission channel, means for differentially combining a portion of the energy in said load circuit with the output energy of said auxiliary transmission channel, means for impressing the combined differential energy upon the input of said feedback channel, and further means for impressing the output energy of said feedback channel upon the inputs of both said main and auxiliary transmission channels.

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