

April 9, 1935.

R. HOFER

1,997,407

AMPLIFIER

Filed Sept. 5, 1931

3 Sheets-Sheet 1

Fig. 1

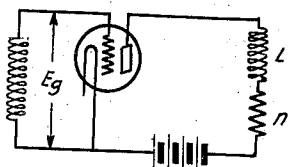


Fig. 2

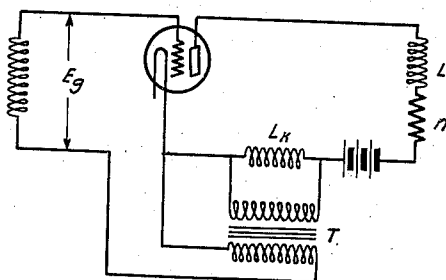


Fig. 3

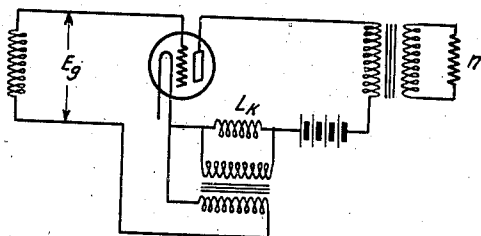


Fig. 4a

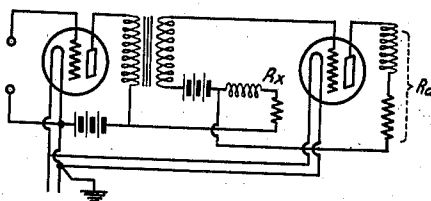


Fig. 4b

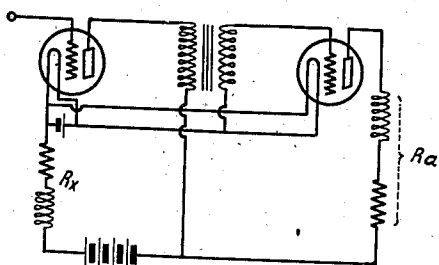
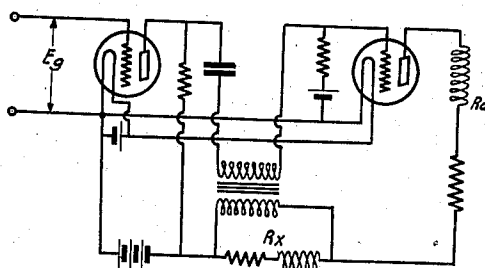


Fig. 5



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Fig. 6a

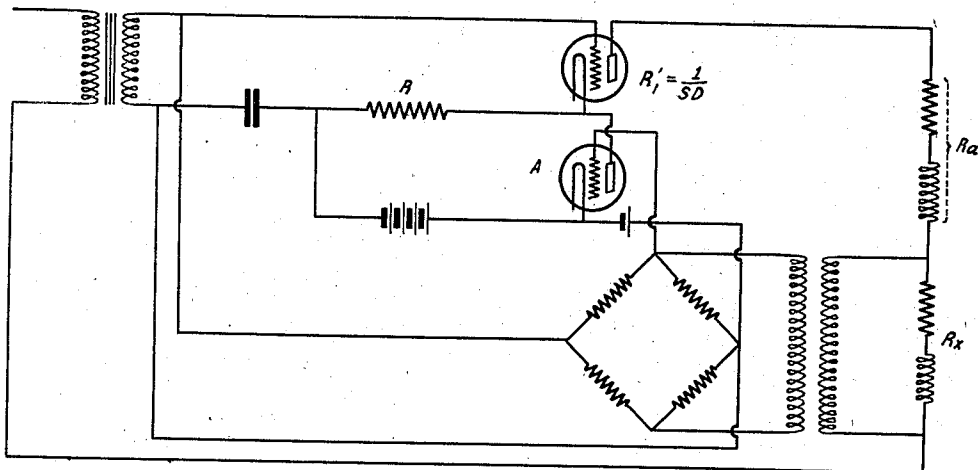
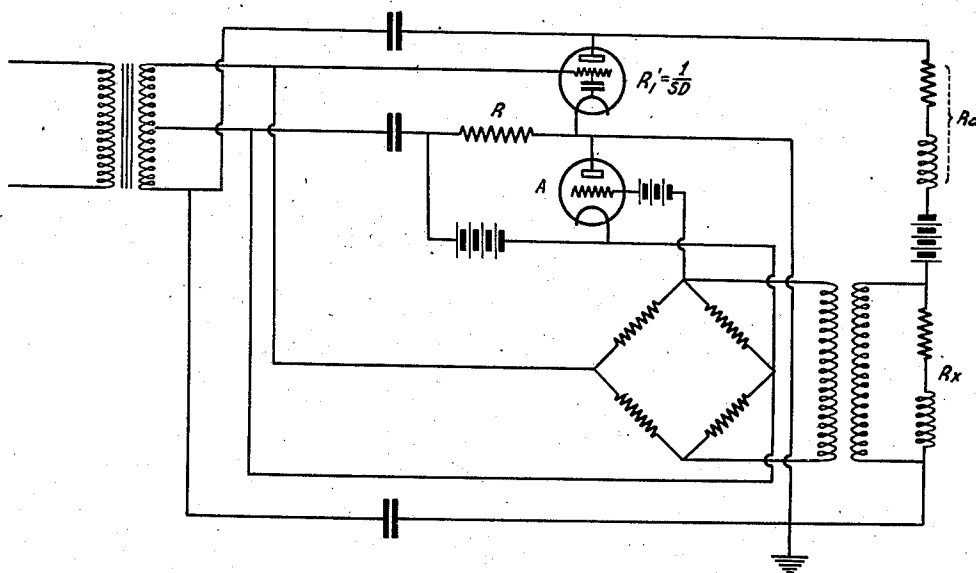


Fig. 6b



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Fig. 7a

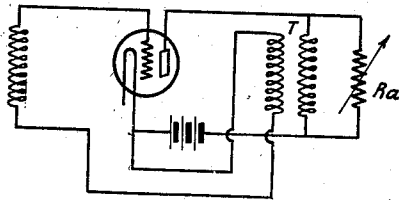


Fig. 7b

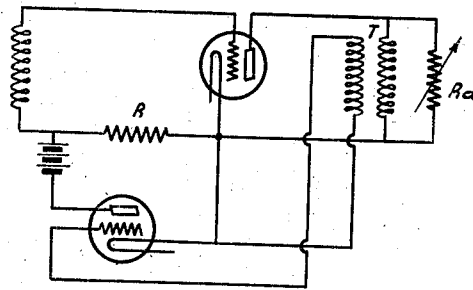
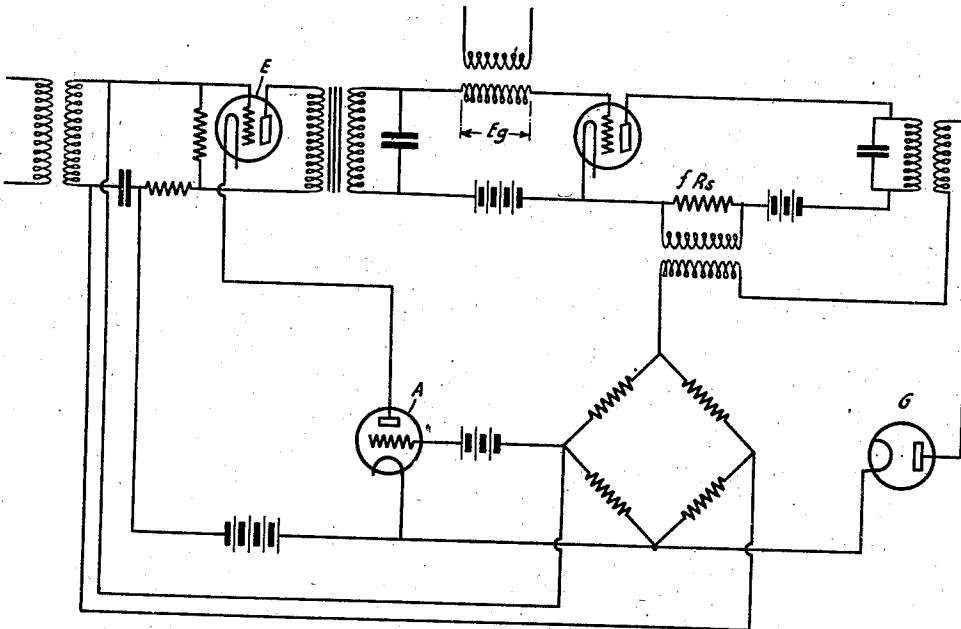


Fig. 8



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5 Claims. (Cl. 179—171)

The present invention is concerned with a method adapted to compensate distortions by regeneration or feed-back of suitable phase relation and size, said distortions being occasioned in thermionic-tube amplifier circuit schemes by the use of frequency-dependent impedances in the plate circuit, by the working within non-linear curve portions, and the like.

In the drawings, Figure 1 represents a circuit arrangement shown in diagrammatic form used to explain the invention;

Figure 2 shows a simplified form of the invention wherein the output and input circuits are coupled;

Figure 3 shows a circuit arrangement incorporating the invention wherein a load is coupled through a transformer;

Figures 4a and 4b illustrate diagrammatically two embodiments of the invention wherein distortions are suppressed;

Figure 5 shows the invention applied to a resistance coupled amplifier;

Figures 6a and 6b illustrate in diagrammatic form certain embodiments of the invention utilizing a bridge arrangement;

Figures 7a and 7b show the invention applied to differentially arranged circuits; and,

Figure 8 is a diagrammatic representation of a circuit incorporating a mixing tube arrangement.

Suppose a load, or consuming, device contained in the amplifier circuit has a useful resistance n and reactive resistance (reactance) $j\omega L$ (see Fig. 1); and suppose the problem is to deliver the same useful power inside a relatively great range of frequencies. If the internal tube resistance is constant, then there exists the well known relation:

$$\frac{E_g}{D} = J(R_i + n + j\omega L)$$

For the lowest frequency to be transmitted there is $\omega L \sim 0$, and for the highest frequency $\omega L > n$.

According to this invention, a potential is regenerated which is in phase coincidence with that acting at the impedance as indicated, for instance, in Fig. 2. If the inductance L_k and the transformer T were free from damping and stray, or leakage, and if, further, the primary resistance of the transformer has been chosen high compared with ωL_k , then there holds good for the stationary state the following equation:

$$\frac{E_g}{D} + j\frac{\omega L_k u}{D} = J[R_i + n + j\omega(L_k + L)]$$

where

$$u = \frac{w_2}{w_1}$$

the relationship between the secondary and the primary turns of the transformer. Choosing,

for instance, L_k and u in such a way that the relation

$$L + L_k \left(1 - \frac{u}{D}\right) = 0,$$

or

$$L_k = \frac{LD}{u - D}$$

is complied with, then the distorting effect of the impedance will be neutralized.

What should be kept in mind is that the circuit apparently behaves as if no distorting impedance were present, though the actual plate alternating current increases with the frequency. By regeneration, the current, for the same original grid alternating current potential, remains unaltered inside the desired frequency range; as a result the plate alternating current potential, in the presence of a higher frequency ω is increased comparatively with lower frequencies in the ratio:

$$\sqrt{\frac{n^2 + \omega^2(L + L_k)^2}{n}}$$

In practice such a circuit scheme would result in lower regeneration inasmuch as the regeneration quantities L_k , T are not free from damping. However, L_k as a rule is of such low value, while the resistance of the transformer generally will be so high, that compensation of such loss of regeneration, feasible for instance by connecting a resistance in the plate circuit, may be dispensed with. The transformer can be obviated by feed-back to the grid circuit of the cascade preceding the last, though in that instance the said cascade or stage itself should not cause any appreciable shift in phase.

Fig. 3 shows diagrammatically a load coupled by means of a transformer. In this case, by the aid of suitable feed-back, the harmful leakage reactance (inductance) occasioned at higher frequencies may be neutralized. In the same manner such detrimental resonance effects as may be caused (by stray of the transformer) may be eliminated. In order to suppress distortions occasioned by the variability of the internal tube resistance, or an external resistance, it is here suggested to couple against each other amplified oscillations in a suitable way. Preferably, the generating and the amplified oscillations of the output circuit are first compared in some suitable manner, and then only the distorted oscillations are differentially coupled to a reinforced extent, this resulting in a stable state, in such a way that a very insignificant amount of residual distorted oscillations suffices for the control and regulation of the desired anti-distortion waves.

When a tube is modulated beyond the straight portion of its characteristic, then the internal impedance R_i will vary, this variation occurring

in accordance with the prevailing aggregate current. Side by side with the non-linear distortions of the fundamental wave there arise distorting higher harmonics.

5 In Figs 4a and 4b two fundamental embodiments are shown by way of example for the suppression of these distortions in the case of a transformer-coupled amplifier. Referring to Fig. 4a the differential coupler resistance R_x is connected
10 in the secondary circuit, while in the example illustrated in Fig. 4b it is contained in the primary circuit. In choosing the dimensions for the same, the ratio of transformation of the transformer U must be taken into consideration. R_x comprises
15 an ohmic and an imaginary component the size of which corresponds to the phase angle of the originally existing circuit quantities (resistances). If conditions are chosen appropriately the counter E. M. F., will be transferred almost completely
20 to the capacity between the grid and the cathode of the last, or power tube.

Fig. 5 shows an embodiment incorporating the basic idea of the invention as applied to a resistance-coupled amplifier, more particularly
25 speaking to the input stage thereof. In order that the potential practically speaking may be wholly brought to the capacity between grid and filament, the differential coupling resistance or impedance R_x is brought to act upon the grid circuit
30 through a transformer. Essentially more efficient is the compensation of non-linear distortions if the undistorted component of the useful oscillation is compensated and only the non-linear portion optionally amplified, is brought in differential
35 coupling in the grid circuit so that the non-linear distortions are almost wholly suppressed without the linear gain being diminished.

Some fundamental forms of construction are shown in Fig. 6a and Fig. 6b in diagrammatic
40 form. Applying the two potentials, i. e., the primary potential impressed upon the grid circuit, and the output potentials, for example, to opposite diagonals of a bridge arrangement, then first any direct reaction of the plate currents upon
45 the preceding amplifier stage is precluded. A bridge resistance across the terminals of which the input potentials and the linearly amplified output potential compensate each other, is associated with the grid and the cathode of compensator tube A.

Now, as long as no distortions arise no potentials will be amplified by tube A. But, when non-linear distortions occur these will in an amplified
50 measure be caused to become operative in phase opposition in the grid circuit. The stable state is attained when the still existent distortion potentials control so much compensating potential in the grid circuit of the main tube that the predominant balance of the distortion is compensated. Fig. 6a shows schematically an arrangement
60 of this kind. The balance, or simulation, R_x is united with the bridge through a transformer. In the presence of corresponding stepping up R_x may be reduced. In order that, on the one hand, amplification by the compensating
65 scheme may not be diminished, while on the other hand, the distorting potential may be applied as much as possible to the resistance between grid and cathode, it is pre-supposed that R_x , as well
70 as the resistance transferred by the transformer of the preceding cascade, is small compared with the grid-cathode reactance of the main tube.

In the scheme shown in Fig. 6b the secondary winding of the grid transformer of the power, or
75 end, tube comprises two like parts, only one-half

of the secondary winding furnishing the grid and compensating potential. The anti-distorting currents flow through both halves of the secondary winding in opposite directions so that reaction upon the previous cascade is practically precluded.

In the case of variable external resistance usually no "form-constant" alternating current, but merely freedom from distortion of the terminal voltage of the variable resistance is desired.
10 Hence, it is here necessary to differentially couple the terminal potential of the load.

Arrangements of this kind are schematically shown in Figs. 7a and 7b. The transformer T is assumed to leave the phase conditions practically unaltered. The resistance of the primary inductance therefore should be high compared with the other resistances in the plate circuit for the lowest frequency to be transmitted. It is also possible to insert a tube for separation as
20 in Fig. 7b. As regards the operation of this arrangement the following may be stated.

The undistorted oscillations are counter-coupled, and so are the harmonic distorting frequencies due to the variation of the internal tube
25 impedance. The gain decreases by the counter-coupling, and the non-linear distortions of the tube decrease likewise. Efficient correction of distortion according to the method hereinbefore described may be used not only in amplifier circuit schemes, but also in modulator stages of transmitters; all that is required in that case is a rectifier.

Fig. 8 shows diagrammatically such a distortion-correcting scheme comprising a "mixing
35 tube" arrangement (grid potential telephony). In this connection, generally speaking, the following points must be noted: By altering the grid biasing potential (or the operating potential in parallel tube modulation) at tonal rhythm, the
40 internal tube impedance is changed, and it is to this alteration of the tube resistance that the arising of the side-band oscillations is due. As long as the modulation curve is straight, the impedance has a constant value for the side-band currents and the modulation is free from
45 distortion. When this characteristic curve ceases to be straight it is well known that distortions are produced in the form of higher side-band frequencies.

For side-band frequencies closely adjacent to the carrier the outer resistance of the stopper circuit is still ohmic in nature; for this reason the enveloping curve of the modulated oscillation is co-phasic with the audiofrequency excitation. In case of modulation by higher notes the outer resistance (reactance) for the respective side-band frequencies often becomes appreciably inductive or capacitive. For this reason the enveloping curve of the oscillation modulated
60 by high frequencies presents a rather marked phase shift in reference with the audiofrequency excitation. Hence, the entire circuit must be simulated in order that, after rectification, an audiofrequency potential being in phase
65 coincidence with the excitation may be impressed upon the standard bridge.

Referring to Fig. 8, f/R_s is a simulation of the side-band reactance of the radiofrequency tube. Instead of the connection of the compensator
70 resistance for the outer circuit which is here not feasible, the rectifier circuit is coupled therewith. It is presupposed in this connection that the resistance of the rectifier and of the bridge is high compared with $fR_s + j\omega L_s$ so that the radio-
75

frequency will practically undergo no further phase shift as a result of the rectifier arrangement. Now, if the load of the audiofrequency power tube E is purely ohmic in nature, then the input potential may be compensated by the undistorted oscillations coming from the rectifier in the bridge so that here again merely the distortion frequencies are induced in the grid circuit by means of the distortion-corrector tube A in phase opposition, whereby any desired correction of distortion will be attainable according to the gain of the tube A.

In a similar way introduction of distortion-correcting potential could be effected in the plate circuit of the power tube E even if the compensator potential had been derived from this circuit. As long as the whole phase shift of the radiofrequency circuits coupled with the transmitter and of those provided in the receiver circuits remain insignificant for the side-band frequencies there results furthermore a chance of so modulating the radiofrequency by the use of anti-distortion detectors resembling the detector customary in receiver apparatus, that the result of demodulation at the receiving end is practically free from distortion. In the case of quadratic rectification, as for example considerable non-linear distortions are caused as is well known, after demodulation, whenever the modulation exceeds the limit of, say 20-30 per cent. By employing a so-called quadratic detector (i. e., a detector operating according to a square law), instead of G, Fig. 8, distortions would be obviated almost entirely even in the presence of higher modulations if a similar receiving detector is used.

While I have indicated and described several systems for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organizations shown and described, but that many modifications may be made without departing from the scope of my invention as set forth in the appended claims.

What is claimed is:

1. In combination with an amplifier including in its output circuit a load introducing distortion therein, a bridge circuit, means for connecting the amplifier input and output circuits to opposite diagonals of said bridge circuit, an amplifier for distortion currents, means for connecting the input of the second amplifier across an arm of said bridge, and means for connecting the output of said second amplifier to the input circuit of said first amplifier.

2. In combination with an amplifier including in its output circuit a load introducing distortion therein, a bridge circuit, means for connecting the amplifier input and output circuits to opposite diagonals of said bridge circuit, an amplifier for distortion currents, means for connecting the input of the second amplifier across an arm of said bridge, means for connecting the output of said second amplifier to the input circuit of said first amplifier and additional means for coupling the said load to the input circuit of said first amplifier.

3. In combination with an amplifier provided with input and output circuits, an impedance load associated with the output circuit normally giving rise to distortion therein, a bridge circuit, connections between the amplifier input and opposite points of the bridge, a transformer connecting the said load to a pair of conjugate points of the bridge, a second amplifier, means for connecting the input electrodes of the second amplifier across an arm of the bridge, and means for connecting the output electrodes of the second amplifier to the input circuit of the first amplifier.

4. In combination with an amplifier provided with input and output circuits, an impedance load associated with the output circuit normally giving rise to distortion therein, a bridge circuit, connections between the amplifier input and opposite points of the bridge, a transformer connecting the said load to a pair of conjugate points of the bridge, a second amplifier, means for connecting the input electrodes of the second amplifier across an arm of the bridge, and means for connecting the output electrodes of the second amplifier to the input circuit of the first amplifier and a rectifier in series with the secondary of said transformer.

5. In combination with a signal amplifier including an electronic tube and having input and output circuits, said output circuit having included therein an impedance giving rise to signal distortion therein and said circuit as a whole possessing a changing resistance characteristic with variations in the frequency of the signal energy handled thereby giving rise to further signal distortion, means for compensating for all of said distortion comprising a link circuit between the output and input circuits to facilitate the transfer of energy from said output circuit to said input circuit, said link circuit being provided with means to simulate both the signal distorting characteristics of the impedance and the signal distortion due to the variable resistance characteristics of the system and to impress the transferred energy from said output circuit to said input circuit in such phase and magnitude with respect to the normal flow of energy through the system that the distortion of the signal energy is compensated to any desired extent said link circuit including a bridge circuit, connections between the amplifier input and opposite points of the bridge, a transformer connecting at least one of the output impedances to a pair of conjugate points of the bridge, a second electronic tube amplifier, means for connecting the input electrodes of the second tube across an arm of the bridge, and means for connecting the output electrodes of the second tube to the input circuit of the amplifier system.

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