

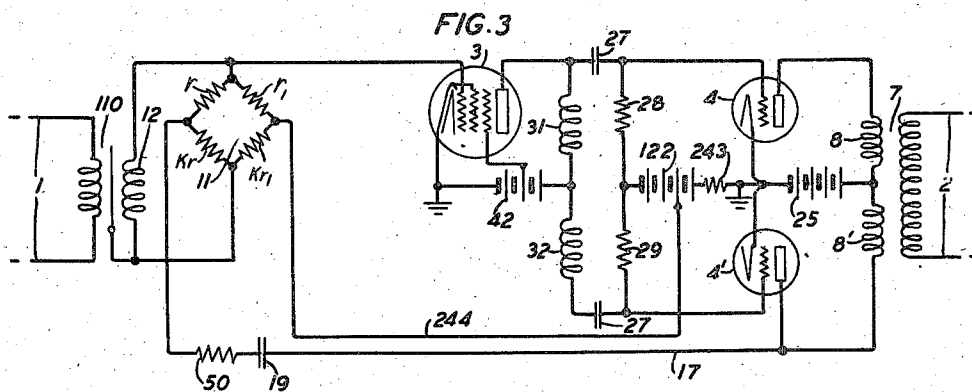
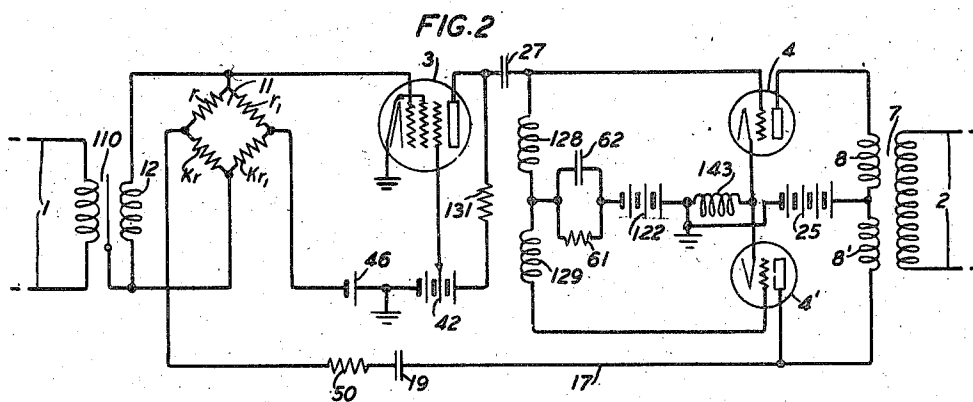
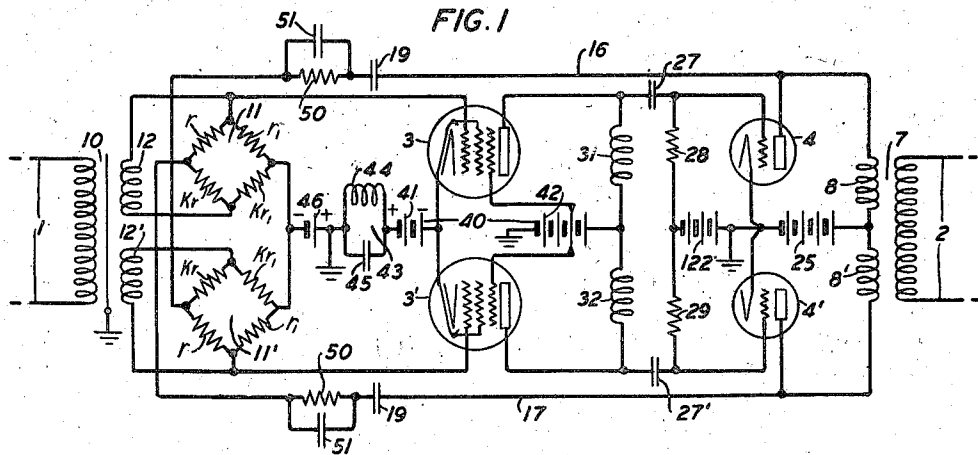
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WAVE TRANSLATING SYSTEM

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WAVE TRANSLATING SYSTEM

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This invention relates to wave translation and especially to retroaction or feedback in wave translating systems as, for example, in systems involving vacuum tubes or electric wave amplifying devices.

An object of the invention is to control transmission properties as, for example, modulation or transmission efficiency, in such systems.

It is also an object of the invention to control feedback in such systems or to facilitate application of feedback in such systems.

A further object is to reduce singing tendency in such systems, especially amplifiers or systems involving push-pull stages that feed back a portion of the output waves in gain-reducing phase and in amount sufficient to reduce distortion below the distortion level without feedback.

In one specific aspect, the invention is embodied in such an amplifier in which the singing tendency is a tendency to sing around the feedback loop caused by parallel operation of the push-pull vacuum tubes or amplifying elements and, in accordance with a feature of the invention, the tendency is reduced by auxiliary negative feedback without materially lowering the amplifier gain.

The auxiliary feedback can be, for example, negative feedback around one stage or an odd number of stages of the vacuum tubes or amplifying elements for suitably altering the propagation (around the main feedback loop) of transmission that (in passing around the main feedback loop) passes through the push-pull tubes in the parallel mode of propagation, to prevent such transmission from resulting in objectionable tendency toward singing around the main feedback loop.

The auxiliary feedback voltage can be derived, for example, from a mid-branch of a balanced circuit of an amplifying stage, (so that it will include only transmission passing through the two sides of the balanced circuit in parallel), in order to avoid materially reducing the amplifier gain.

In its specific aspect mentioned above, the invention may be, for example, a two-stage amplifier comprising a single-tube stage driving a push-pull stage. The normal mode of propagation through the push-pull stage is the push-pull mode. Transmission so propagated may be called the normal transmission. For this normal transmission, one of the push-pull tubes has its plate potential approximately opposite in phase to the potential of the driver-tube grid. A feedback connection from this one plate to the driver-tube

grid may be provided to produce negative feedback of normal transmission, i. e., of transmission propagated through the push-pull stage in the normal mode.

The feedback loop for this negative feedback may be referred to as the main feedback loop; and the feedback around this loop of normal transmission or transmission propagated in the normal mode through the push-pull stage may be called the normal or main feedback.

Due to unbalance of the push-pull circuit, there may be undesired propagation of transmission through the push-pull stage, this transmission being propagated in the parallel mode, i. e., with the two tubes of the push-pull stage effectively in parallel. This transmission may be called the parallel transmission. For this parallel transmission, the plates of the push-pull stage unfortunately may have their potential in phase with that of the driver-tube grid. This condition may result in strong tendency toward singing around the main feedback loop, especially since the driver stage may be a high-gain stage. This high gain may be desired, for example, in order to give the loop gain for the normal or main feedback around the main feedback loop (i. e., the decibel gain for one trip of the normal transmission around the main feedback loop) a high value, e. g., several times ten decibels. The large loop gain is desirable, for example, for producing large reduction of distortion. The distortion reduction required may be especially large in case the push-pull stage is operated as a class B amplifier.

The singing tendency can be effectively reduced without materially reducing the amplifier gain, for example, by producing local negative feedback around the driver tube of the parallel transmission to the exclusion of the normal transmission. As one example of ways in which this may be done, a voltage can be derived from the mid-branch of the balanced input circuit of the push-pull tubes, and fed back to the driver-tube grid in gain-reducing phase, i. e., in such phase as to reduce the derived voltage.

Other objects and aspects of the invention will be apparent from the following description and claims.

Figs. 1, 2 and 3 are circuit diagrams of three forms of the invention.

Fig. 1 shows a two-stage push-pull amplifier for amplifying waves received from circuit 1 and transmitting the amplified waves to circuit 2. The waves may be, for example, speech waves or a broad band of carrier waves transmitting a number of speech messages by multiplex carrier

telephony. The first stage of the amplifier may be a high gain stage substantially free from non-linear distortion, comprising two similar vacuum tubes 3 and 3', shown by way of example, as pentodes. The second stage may be a power stage. It comprises two tubes 4 and 4' which are also alike and which are shown, by way of example, as triodes.

The tubes 4 and 4' are connected to the outgoing circuit 2 through output transformer 7 having closely coupled primary windings 8 and 8'.

The incoming circuit 1 is connected to the tubes 3 and 3' through input transformer 10 and bridge networks 11 and 11'. The transformer has secondary windings 12 and 12'. The winding 12 forms one diagonal of bridge 11; and the winding 12' forms one diagonal of bridge 11'. The four ratio arms of bridge 11 comprise resistances r_1 , kr_1 , kr and r , respectively, the grid and cathode of tube 3 being connected to receive the voltage across arm r_1 . The four ratio arms of bridge 11' likewise comprise four resistances r_1 , kr_1 , kr and r , the grid and cathode of tube 3' being connected to receive the voltage across this resistance r_1 .

The normal mode of propagation of transmission through the two push-pull stages is the push-pull mode, and transmission so propagated may be called the normal transmission. For this normal transmission, the potentials of the plate of tube 4 and the grid of tube 3 are approximately opposite in phase, and the potentials of the plate of tube 4' and the grid of tube 3' are approximately opposite in phase.

A feedback path comprising two feedback connections 16 and 17, each including a stopping condenser 19, connects the output circuit of the amplifier to the amplifier input circuit, to produce negative feedback of normal transmission, for example, for reducing distortion. The feedback loop for this negative feedback may be referred to as the main feedback loop; and the feedback around this loop of normal transmission may be called the normal or main feedback. The gain reduction effected by this feedback may be large as, for example, several times ten decibels. The gain of the amplifier without feedback should then correspondingly exceed the gain with feedback. For instance, the gain without feedback may be of the order of 65 decibels, and the feedback may reduce the gain to, say, a value of the order of 35 decibels.

With the two-stage balanced amplifier, the normal feedback is obtained in the desired phase by reversing the feedback leads 16 and 17, i. e., crossing them over from one side of the push-pull circuit to the other side, as disclosed in E. Peterson Patent 1,955,827, April 24, 1934. Thus, lead 16 is connected from the plate of tube 4 (which is in the upper side of the push-pull circuit) to the bridge circuit 11' in the input circuit of tube 3' (which is in the lower side of the push-pull circuit); and lead 17 is similarly connected between the plate of tube 4' (which is in the lower side of the balanced circuit) to the input bridge circuit 11 of tube 3 (which is in the upper side of the balanced circuit). The bridge circuits 11 and 11' render the feedback path comprising connections 16 and 17 conjugate to windings 12 and 12' and circuit 1 at balance of the bridges, as pointed out in the above-mentioned Peterson patent.

Due to unbalance of the push-pull circuit, there may be undesired propagation of transmission through the push-pull stages, this transmission being propagated in the parallel mode, i. e., with

the two tubes of the push-pull stage effectively in parallel in the case of each stage. This transmission may be called the parallel transmission.

Since this parallel transmission may be fed back through the feedback path comprising the feedback connections 16 and 17, tendency toward singing around the main feedback loop may result. Such singing will be referred to as parallel singing or over-all parallel singing. Unfortunately, the parallel singing tendency may be strong, since the amplifier in the main feedback loop has an even number of stages and may include tubes such as 3 and 3', with large amplification constants. Means for reducing the parallel singing tendency will be described hereinafter.

A plate current supply source 25 and a grid bias potential source 122 are shown for tubes 4 and 4'. The source 122 may bias the tubes for so-called class B operation in which the space current of the tube is interrupted for the order of half the period of the waves to be amplified. Further, the source 122 may maintain the grids always negative during operation of the amplifier. The grid biasing potentials for the tubes 4 and 4' are supplied through high resistances 28 and 29, respectively.

The plate of tube 3 is connected to the grid of tube 4 through a stopping condenser 27; and the plate of tube 3' is connected to the grid of tube 4' through a stopping condenser 27'.

A plate current supply source 40 supplies direct space current for the tubes 3 and 3' through choke coils 31 and 32, respectively, which are closely coupled. The source 40 comprises two sources 41 and 42 serially connected by an impedance 43 shown, by way of example, as an inductance element 44 and a capacity 45 in parallel. (Sources 42 and 25 may be common, if desired). Impedance 43 is common to the mid-branch of the balanced input circuit and the mid-branch of the balanced output circuit of tubes 3 and 3', and provides a mid-branch local negative feedback of alternating currents in the high-gain driver stage. This feedback lowers the gain of the driver stage for parallel transmission, but not for normal transmission. It serves to reduce parallel singing tendency (or, in other words, to prevent singing around the main feedback loop due to propagation of parallel transmission around the main feedback loop), without materially reducing the amplifier gain (i. e., without reducing the gain of the amplifier between circuits 1 and 2 for normal transmission). Since the impedance 43 is in the grid mid-branch of the push-pull stage comprising tubes 3 and 3', the normal transmission in the grid circuits of these tubes is in one direction or phase in impedance 43 at any given instant for transmission through tube 3 and is in the opposite direction or phase in impedance 43 at the same instant for transmission through tube 3'; and so the normal transmission produces no voltage drop across impedance 43 in these grid circuits. However since it is of course impractical to make the parallel opposing impedance of coils 31 and 32 zero, parallel transmission through the two sides of the push-pull stage may become appreciable. For such parallel transmission, in impedance 43 the plate current of tube 3 passing through impedance 43 and coil 31 at any given instant has the same direction or phase as the plate current of tube 3' passing through impedance 43 and coil 32; so the parallel transmission produces a voltage drop in the impedance 43 and this appears as a negative

feedback voltage on the grids of the tubes 3 and 3'.

The close coupling of coils 31 and 32 and likewise the close coupling of coils 8 and 8', tends to short-circuit the parallel singing path and eliminate parallel singing. The mid-branch feedback around the driver stage is effective in preventing parallel singing regardless of this close coupling, and is especially useful for this purpose when the close coupling is inadequate for the purpose.

By having the resistance of the inductance element 44 small, the direct current voltage drop across the impedance 43 can be made small. Moreover, by having the voltage of source 41 equal and opposite to this direct current voltage drop across 43, the direct current potential of the cathodes of tubes 3 and 3' can be kept at ground potential or the potential of the terminal of impedance 43 electrically remote from the cathodes, negative grid bias for the tubes being supplied by a voltage source 46. The source 46 may maintain the control grids of the tubes always negative during operation of the tubes and condition the tubes for class A operation. The condenser 45 serving in connection with the inductance 44 as the impedance across which the auxiliary feedback voltage is produced, may have a capacity of the order of 800 micro-microfarads, for example.

Feedback resistors 50 are shown in leads 16 and 17 for controlling the amount of feedback. Small capacities 51 are shown in shunt to these resistors. These capacities reduce the phase shift around the main feedback loop at very high frequencies to prevent a series sing, i. e., singing due to transmission propagated through the push-pull stages in the push-pull mode. The value of these capacities is not critical. Each may have a value of the order of 50 micro-microfarads, for example.

Fig. 2 shows an amplifier circuit similar to that of Fig. 1, but with a single tube or single-sided driver stage connected to circuit 1 by an input transformer 110 and driving the push-pull stage through a coupling circuit comprising a plate-circuit resistor 131 for tube 3, the coupling condenser 27 and a balanced retard coil or autotransformer having its balanced windings 128 and 129 tightly coupled. Over-all negative feedback is obtained by a feedback path through connection 17 which gives the desired reverse phase of feedback voltage by connecting the plate of tube 4' to the input bridge 11.

Using a single tube in the first stage not only reduces the required amount of apparatus, but reduces the power drain of the complete amplifier. The latter factor is especially important under no-load conditions when the power drain of the small, high-gain driver stage is comparable to the drain of the class B power stage.

Such a two-stage, three-tube negative feedback amplifier is subject to a kind of over-all singing which may be called parallel singing and which is somewhat similar to the over-all parallel singing discussed in connection with the four-tube circuit of Fig. 1. The mode of oscillation is such that the output tubes operate in parallel, (that is, with the potentials of the two grids the same instead of 180 degrees out of phase), though the oscillations are transmitted through the feedback path and the single-tube stage as a series disturbance.

In such over-all singing with parallel operation of the power stage, the coupling between the stages is through the parallel opposing impedance of the interstage autotransformer, while the out-

put tubes faces the parallel opposing impedance of the output transformer. If either of these transformers had their balanced coils perfectly coupled and had zero resistance, such mode of oscillation (i. e., this over-all singing with parallel operation of the two sides of the power stage) would be impossible; but such construction is, of course, impracticable.

To reduce the over-all parallel singing tendency, an impedance shown, for example, as an inductance 143, is connected in the mid-branch of the balanced input circuit and the mid-branch of the balanced output circuit of the push-pull stage. This inductance functions similarly to the inductance 43 of Fig. 1. It produces local negative feedback of parallel transmission around the stage in which it is connected, lowering the gain of that stage for parallel transmission and serving to reduce the over-all parallel singing tendency.

In tests of a voice frequency, negative feedback, two-stage, three-tube amplifier, such as the amplifier of Fig. 2, two types of parallel singing were encountered. Neither type occurred except when feedback was used. Although the frequency of the first type of sing (20 to 60 kilocycles) was not greatly discriminated against by the output transformer, due to the balance in the parallel path no appreciable output was obtained in the load circuit at the singing frequency. This singing was stopped by using the impedance 143 in the common-plate-grid mid-branch of the class B stage, the specific impedance employed being an inductance of 22 milhenrys.

The second type of singing occurred at critical values of load (transmission level). A Braun tube pattern showed the singing as highly damped oscillations occurring over a fraction of the fundamental cycle and synchronized in frequency with a high harmonic of the fundamental frequency applied. This singing was stopped by inserting a resistance 61 and shunt capacity 62 in the balanced stage grid mid-branch of such values as to approximately resonate out the parallel opposing reactance of the interstage coupling retard 128, 129 near the singing frequency.

To avoid increase of third order distortion and consequent limitation of the fundamental output available, it was found desirable to keep the impedance 143 introduced in the plate circuit of the class B stage as small as possible.

The circuit of Fig. 3 avoids the necessity of introducing such impedance in the plate circuit of the class B stage and has the advantage of introducing the local feedback in the linear, high-gain driver stage; yet it retains the feature that the auxiliary or local negative feedback is so effected as to avoid reducing the gain for normal transmission or, in other words, to avoid materially reducing the amplifier gain.

This circuit is a two-stage, three-tube, negative feedback amplifier generally similar to that of Fig. 2. However, the feedback voltage for the auxiliary negative feedback is derived from a feedback impedance in a portion of the grid circuit of the class B stage that is traversed by the parallel transmission to the exclusion of the normal transmission; and the voltage so derived is fed back to the grid of the tube in the high-gain linear driver stage.

This feedback impedance is shown as a resistance 243 in the mid-branch of the balanced grid circuit of the class B stage. The cathodes of both stages are shown grounded, and the terminal of the resistance 243 electrically remote from ground is shown connected to the input

bridge 11 through a conductor 244 and a portion of the grid-biasing battery 122 sufficient to supply the grid bias for tube 3.

Any voltage drop that appears across the impedance 243 is fed back into the grid circuit of the driver stage. Any voltage applied to the two grids of the balanced stage in parallel, i. e., in the singing mode, will appear across this impedance 243 and, therefore, will be fed back, reducing the gain of the driver stage for that mode of transmission and reducing over-all parallel singing tendency. However, any voltage which appears across the two grids of the balanced stage in series will balance out across the impedance 243 and hence this impedance will not affect the gain of the amplifier for normal transmission, or, in other words, will not materially reduce the over-all amplifier gain.

What is claimed is:

1. An amplifier with a feedback loop comprising a push-pull stage having a mid-branch circuit and connections that introduce a phase reversal in transmission around the loop when the transmission is in the push-pull mode through the push-pull stage but not when the transmission is in the parallel mode through the push-pull stage, and means comprising a feedback impedance in said mid-branch circuit producing negative feedback around a portion of the amplifier stages in said loop for transmission whose passage through said push-pull stage is in the parallel mode but not for transmission whose passage through said push-pull stage is in the push-pull mode.
2. An amplifier with a feedback loop comprising a push-pull stage having a mid-branch circuit and connections that introduce a phase reversal in transmission around the loop for transmission in the push-pull mode through the push-pull stage but not for transmission in the parallel mode through the push-pull stage, and means for reducing parallel singing tendency in the amplifier without materially lowering the amplifier gain, said means comprising a feedback impedance in said mid-branch circuit producing feedback around a portion of the amplifier stages in said loop that reduces the gain around said loop for transmission taking place in the parallel mode through said push-pull stage, said portion of the amplifier stages including a stage having but one amplifying element.
3. An amplifier with a feedback loop producing negative feedback around an even number of stages including a push-pull stage, and means producing negative feedback around an odd number of those stages in a mode that suppresses parallel singing in the amplifier without materially reducing the amplifier gain.
4. An amplifier with a feedback loop producing negative feedback around an even number of

stages including a push-pull stage and another stage having but one amplifying element, and means producing around an odd number of those stages including said other stage, feedback that reduces the gain around said loop for transmission in the parallel mode through said push-pull stage without reducing the gain around said loop for transmission in the push-pull mode through said push-pull stage.

5. An amplifier with a normal negative feedback channel around a feedback loop including a single-sided stage feeding a push-pull stage, and a circuit feeding back from the common branch of the input circuit of the push-pull stage to the single-sided stage waves that, without reducing the gain around the normal feedback channel, reduce tendency toward singing around a feedback channel including the two sides of the push-pull stage in parallel.

6. An amplifier with a feedback loop that includes a push-pull stage and produces negative feedback in said amplifier for transmission in the push-pull mode through said stage, and means producing feedback from a mid-branch circuit of said push-pull stage around an odd number of amplifier stages in said loop, said stages including said push-pull stage.

7. An amplifier comprising a push-pull stage having a mid-branch circuit, a normal negative feedback channel around a feedback loop including said push-pull stage, and connections comprising a feedback impedance in said mid-branch circuit feeding back in the amplifier waves that, without reducing the gain around the normal feedback channel, reduce tendency toward singing around a feedback channel including the two sides of the push-pull stage in parallel.

8. An amplifier with a feedback loop that includes a push-pull stage and produces negative feedback in said amplifier for transmission in the push-pull mode through said stage, and means producing feedback from a mid-branch circuit of said push-pull stage around a feedback loop having an odd number of amplifier stages one of which is in said loop.

9. The method of operating a signal wave amplifying system with a push-pull stage which comprises producing negative feedback in the system by transmission of the signal waves in a given mode around a feedback loop that includes said stage, producing positive feedback around said loop of waves transmitted through said push-pull stage in the parallel mode of transmission, and reducing the gain around the loop for the latter waves by auxiliary negative feedback in a portion of the loop of those waves to the exclusion of waves transmitted in said given mode.

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