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ELECTRIC WAVE AMPLIFIER WITH FEEDBACK

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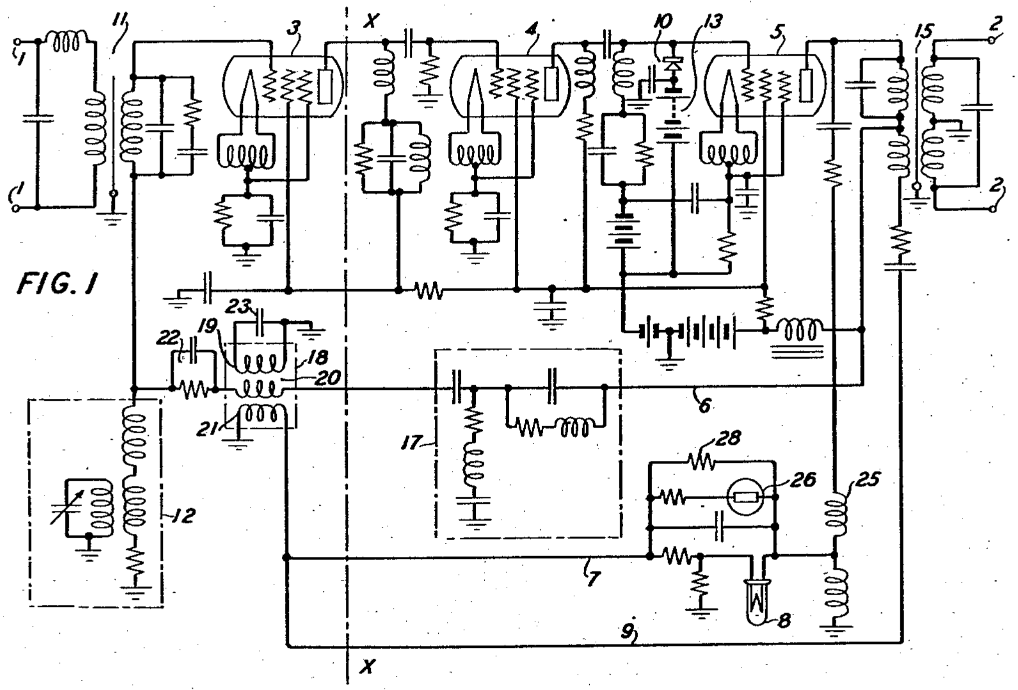

FIG. 1

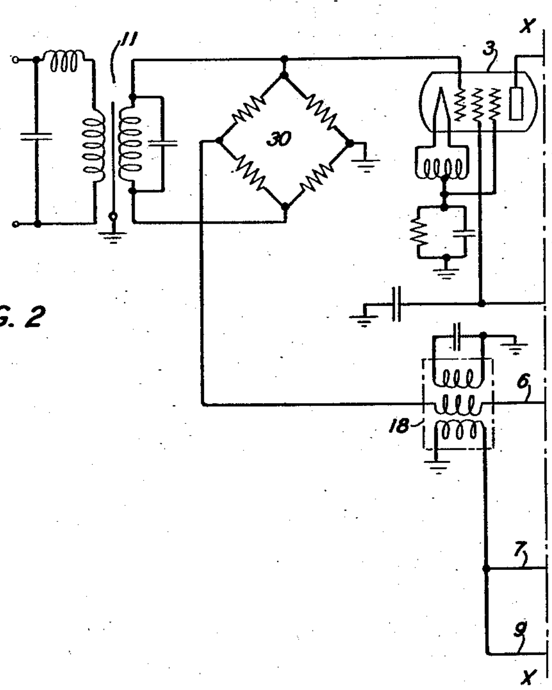

FIG. 2

INVENTOR
J. O. EDSON
BY
N. S. Ewing
ATTORNEY

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ELECTRIC WAVE AMPLIFIER WITH FEEDBACK

James O. Edson, Great Kills, N. Y., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

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8 Claims. (Cl. 178—44)

This invention relates to wave translating systems and methods involving concurrent regenerative and degenerative wave feedback and to electric wave translating circuits and methods utilizing a wave amplifying element concurrently as a generator of oscillations and as a wave amplifier with negative feedback.

One object of the invention is to provide an improved oscillator-amplifier and more particularly to reduce the deleterious effect that the oscillations generated tend to have on the amplifier and the transmission path in which it is interposed.

A further object is to reduce the tendency of the oscillations generated in an oscillator-amplifier to escape into the source of waves being amplified.

Still another object is to secure in an oscillator-amplifier the benefit of large negative feedback over a wide range of frequencies to be amplified and at the same time to prevent certain undesirable effects heretofore incident to the generation of oscillations at a frequency or frequencies adjacent to the frequency range being amplified. In one aspect the present invention may be regarded as an improvement upon the amplifier-oscillator-modulator organization disclosed in United States patent to C. O. Mallinckrodt, No. 2,231,542, dated February 11, 1941.

In accordance with an embodiment of the present invention a wave amplifier having a large negative feedback over a range of frequencies to be amplified and having also positive or regenerative feedback for the generation of oscillations, is so arranged that the waves being fed back regeneratively are injected into the negative feedback path.

The nature of the present invention and its various features, objects and advantages will appear more fully from a consideration of the embodiments illustrated in the drawing and now to be described.

Fig. 1 illustrates one embodiment of the invention; and

Fig. 2 illustrates a modification thereof.

Referring to Fig. 1, there is shown schematically an electric circuit organization which, like those disclosed in the Mallinckrodt patent, supra, and in United States patent to J. H. Bollman, No. 2,231,558, dated February 11, 1941, is adapted for use at the sending end of a repeatered transmission line system having automatic repeater gain regulation of a type now known in the art. The function of the organization is several-fold: first, it constitutes a stabilized negative feedback amplifier having constant gain for the signals applied to its input terminals; second, it generates pilot oscillations for transmission over the line concurrently with the signals; and, third, it automatically varies the intensity of the generated oscillations in such manner that the average value of the total wave power delivered to the transmission line is substantially constant irrespective of the normal variations in the power content of the applied signals.

In general outline the circuit shown comprises a three-stage amplifier with input terminals 1, output terminals 2, and a gain-reducing negative feedback path 6 extending from the output of the amplifier to the input thereof. Another path 7 extending from the output of the amplifier to a point within the negative feedback path 6 serves to provide sufficient positive feedback at a predetermined frequency that pilot oscillations are generated. A current-dependent element 8 functions in a manner to be described to effect the desired variation in the intensity of the generated oscillations.

It may be assumed by way of specific practical example that the circuit shown is part of a twelve-channel multiplex carrier telephone transmission system and that the waves applied to the input terminals 1 consist of carrier telephone signals ranging in frequency from somewhat more than 12 kilocycles to a few hundred cycles less than 60 kilocycles. There may also be applied with the signals several comparatively feeble pilot waves of constant intensity having frequencies of 12, 28 and 56 kilocycles, for example, which may be used at repeater stations for various regulating functions. It may be assumed further that the pilot oscillations generated within the amplifier have a frequency of 60 kilocycles. It is to be noted that the intensity of these locally generated oscillations may range in the course of the normal operation of the system from substantially zero to a value comparable with the maximum signal output power for which the amplifier is designed.

The mu circuit of the amplifier and the negative feedback circuit 6 in this example are designed in accordance with the teachings of United States patent to H. W. Bode, No. 2,123,178, dated July 12, 1938, to yield maximum uniform gain over the 12 to 60-kilocycle frequency range. The mu circuit gain may be, for example, 110 decibels and the reduction in overall gain due to negative feedback may be 45 decibels, for example. Feedback circuit 7 is designed to provide positive feedback from the output of the amplifier to the input thereof at the desired pilot frequency of 60 kilocycles. The current-dependent device 8 variably controls the amount of loss or attenuation in the positive feedback circuit, thus adjustably fixing the intensity of the generated oscillations, and the loss it introduces is in turn controlled in accordance with the power output of the amplifier.

Considering now the details of the circuit shown, the input terminals 1 are connected to the primary winding of an input transformer 11 through a series inductance and shunting condenser the function of which is to give the transformer a good resistive impedance and substantially constant transmission from 12 to 60 kilocycles. The secondary winding of transformer 11 is shunted by a condenser and by a resistance and condenser in series, the function of which is to by-pass frequencies above the transmitted range and at the same time to give the complete network a good resistive impedance and substantially constant transmission from 12 to 60 kilocycles. The secondary is connected on the one side to the control grid of the amplifying pentode tube 3 and on the other side it is connected through an impedance branch 12 to ground. The cathodes of pentode tubes 3 and 4 are connected through respective condenser-shunted resistors to ground, while the cathode of pentode 5 is grounded through a condenser-shunted resistor and a battery which supplements the plate battery. The suppressor grid in each of the pentodes is conductively connected to its associated cathode, and the respective screening grids are by-passed to ground by condensers. The cathodes are of the filamentary type and are shown in association with respective secondary windings of a filament supply transformer.

The interstage coupling between pentodes 3 and 4 is of the impedance-condenser type with the elements proportioned for a substantially flat gain-frequency characteristic over the frequency range of interest. The interstage coupling between pentodes 4 and 5 is predominantly of the impedance-condenser type for the higher frequencies in the transmitted range and of the transformer-coupled type for lower frequencies, the elements again being proportioned for a substantially flat gain characteristic. Rectifier 10 is a substantially unilaterally conducting device which, on the one side, is conductively connected to the control grid of pentode 5 and, on the other, through a biasing battery 13 to the cathode of tube 5. The rectifier 10 is so poled as to permit current to flow through it only toward the control grid of tube 5, and biasing battery 13 has such voltage that the rectifier becomes conducting only when the signals being amplified become more negative than the cut-off voltage of pentode 5. The output of pentode 5 is delivered to terminals 2 through an output transformer 15 the primary winding of which is tapped to afford a connection for the feedback circuit 6. Further details regarding this manner of securing a negative feedback connection will be found in United States patent to E. H. Perkins, No. 2,210,001, dated August 6, 1940.

The negative feedback circuit 6 extends through the series elements of a T-network 17, one winding 20 of a three-winding transformer 18, and a parallel resistor-condenser combination 22 to the high potential end of the impedance branch 12. The elements of this circuit are proportioned in the usual manner to provide negative feedback of the desired amount and of substantially the same value throughout the 12 to 60-kilocycle frequency range.

The positive feedback connections include a connection from the anode of pentode 5, through a blocking condenser and resistor in series, and a pair of inductively related coils 25, to ground. From the junction of the coils 25 the circuit 7 extends through a T-network including current-dependent device 8, and a winding 21 of the transformer 18, to ground. The third winding 19 of transformer 18 is shunted by a condenser 23 to form a low-loss circuit that is resonant at 60 kilocycles.

The 60-kilocycle waves being fed back through the circuit 7 are thus injected into the feedback circuit 6, and the latter provides a path for them back to the input of the amplifier. The elements making up the circuit 7 are so proportioned as to provide positive feedback from the output of the amplifier to the input for a frequency of 60 kilocycles, and the positive feedback so provided is made sufficiently greater than the negative feedback at 60 kilocycles which takes place through circuit 6 that oscillations can be and are generated.

It is advantageous, because of the relatively low impedance of circuit 7, to make windings 20 and 21 of comparatively few turns, four each for example, and winding 19 of many turns, 340, for example, as in one instanceof practice, for by so doing the desired resonance can be obtained with a condenser of relatively small capacitance. The effect of the resonant circuit 19—23 is effectively to tune the windings 20 and 21 by virtue of the coupling between windings. Its effect on the negative feedback characteristic, in the band of signal frequencies, is largely offset by the resonant circuit associated with impedance branch 12.

An important feature of the circuit as herein disclosed relates to the magnitude of the 60-kilocycle voltage that appears in the input circuit of the amplifier, or more particularly, across the impedance branch 12. This voltage may be regarded as made up of two components, one due to transmission of 60-kilocycle oscillations through the negative feedback path and the other due to 60-kilocycle oscillations transmitted through the positive feedback path. Either of these two components alone may be hundreds of times as great as the difference between the two components. Bearing in mind that either component alone may often be thousands of times as intense as any signal voltages present, one can appreciate the possibility that a substantial 60-kilocycle current may pass through the transformer 11, due to the distributed capacitance of the windings thereof, and into the circuit to which the terminals 1 are connected. Thus, for example, these 60-kilocycle oscillations may enter through a preceding filter into a carrier telephone modulator with sufficient intensity to cause distortion and unwanted modulation products throughout all of the carrier channels. In the present circuit, however, neither of the aforementioned components appears alone across the coupling impedance 12 but only the difference between the two components, and the difference voltage is so small that it can have no substantial effect on the connected circuit.

In order to vary the intensity of the 60-kilocycle oscillations in such relation to the normal variations in the intensity of the signals that the average total power output of the amplifier is maintained substantially constant, the circuit employs an element 8 such that the loss it introduces in the positive feedback path is a function of the intensity of the current transmitted through it. There are various devices having the required characteristic, such as iron-cored coils and transformers, copper-oxide rectifiers and silicon-carbide resistors, but I prefer to use a thermosensitive resistance of such proportions that its temperature and resistance are largely controlled by the intensity of the electric current passing through it, such as the type 13P resistance lamp manufactured by Western Electric Company, Incorporated. The lamp has a positive temperature coefficient of resistance, and for present purposes it is therefore disposed in series in the positive feedback circuit 7. Lamp 8 receives from the output of the amplifier a fixed proportion of the total power output. Hence as the total power output tends, for example, to rise with an increase in signal strength the resistance of the lamp increases, thereby decreasing the amount of positive feedback and the intensity of the 60-kilocycle oscillations. By suitable proportioning of the circuit elements in relation to the electrothermal characteristics of the lamp 8, the total power output of the amplifier may be maintained substantially constant.

The operation of the lamp is in some degree dependent on the ambient temperature. The adverse effect of ambient temperature variations is largely compensated, however, by a current-independent thermosensitive resistor 26. The latter is effectively shunted across the lamp network in the manner shown, and its temperature-resistance characteristic is so chosen as to complement the ambient temperature-resistance characteristic of lamp 8. The thermosensitive resistor 26, in conjunction with shunting resistor 28, also affects the transient response of the oscillation circuit, tending to reduce the amount by which the oscillation intensity overshoots its final value following an abrupt change in the power input to terminals 1. This effect appears, for example, when the oscillation intensity is required to change from zero to substantially its maximum value following cessation of an input pulse so strong as to stop the oscillation. The reduction in overshooting in such circumstances can be and is enhanced by designing transformer 18 to operate near saturation when the oscillation intensity is maximum.

The intensity of the oscillations tends to be affected also by any departure of the load impedance from a preassigned value. This effect is compensated by an auxiliary feedback path 9 which is connected, effectively in parallel with feedback path 7, between the low potential end of the output transformer 15 and transformer winding 21. If the impedance of the load connected across output terminals 2 is, for example, lower than the preassigned value, the output voltage and also the amount of current fed back through path 7 will be lower than normal. The output current, however, will be greater than normal and there will be a corresponding increase in the current fed back through path 9. Thus the reduction in feedback through path 7 is offset by an increase in the feedback through path 9, and the effect of a variation in load impedance is substantially compensated.

In a modification of Fig. 1 a bridge circuit is utilized at the junction of the feedback paths and the input circuit of the amplifier to reduce still further the escape of 60-kilocycle oscillations into the preceding equipment. As illustrated in Fig. 2, four impedance arms are disposed to form a bridge 30 with the secondary winding of input transformer 11 connected across one diagonal, the feedback circuit 6 connected across the other diagonal, and the input to pentode 3 connected across one of the impedance arms. Theoretically, the several impedance arms can be assigned such impedance-frequency characteristics as to render the feedback paths conjugate to the input terminals; practically, one can readily obtain, with relatively few elements, a transmission loss between the input terminals and the feedback paths of 40 decibels at a given frequency, the latter being 60 kilocycles in the present example. Thus, the transmission of 60-kilocycle oscillations into the preceding equipment is reduced greatly in the first instance by injection of the oscillations into the negative feedback circuit, and it is further reduced by the transmission loss interposed by the input circuit bridge.

What is claimed is:

1. An electric wave amplifier comprising an input circuit, an output circuit, and a path connecting said input and output circuits for negative feedback over a broad band of frequencies, and means for generating oscillations at a frequency within the said broad band comprising said amplifier and a positive feedback path extending from said output circuit to a point within said negative feedback path, whereby the intensity of the oscillations effective in said input circuit is substantially less than the intensty of the oscillations fed back through either of said paths alone.

2. An electric wave amplifier comprising an input circuit and an output circuit for the waves to be amplified, a path embracing said amplifier for the negative feedbox of waves within a range of frequencies, means including at least a portion of said amplifier for the generation of oscillations at a frequency within said range whereby the said oscillations are fed back negatively through said feedback path, and means for substantially neutralizing the negative feedback of oscillations comprising means for injecting oscillations from said generating means into said feedback path.

3. An amplifier having input and output terminals, a negative feedback path, and a positive feedback path for the generation of oscillations, said positive feedback path including means for injecting the generated oscillations traversing it into said negative feedback path at a point electrically distinct from the posterior end thereof.

4. A wave amplifying system having a gain-reducing feedback path extending from a posterior point to an anterior point of said amplifying system, an oscillation-generating wave transmission loop comprising a positive feedback path and at least a portion of said amplifying system between said points whereby the said oscillations tend to be fed back through said gain-reducing feedback path to said anterior point, and means for injecting the generated oscillations into the said gain-reducing feedback path at a point electrically intermediate of the extremities of said gain-reducing feedback path.

5. A wave amplifying system having a gain-reducing feedback path extending from a posterior point to an anterior point of said amplifying system, an oscillation-generating wave transmission loop comprising a positive feedback path and at least a portion of said amplifying system

between said points whereby the said oscillations tend to be fed back through said gain-reducing feedback path to said anterior point, means for injecting the generated oscillations into the said gain-reducing feedback path, and auxiliary positive feedback means responsive to changes in load impedance.

6. An electric wave translating system comprising a wave amplifying section, a feedback path embracing said amplifying section and adapted for gain-reducing feedback over a band of frequencies, and a positive feedback circuit affording a path for the generation of oscillations at a frequency within said band, said positive feedback circuit terminating at its anterior end in said first-mentioned feedback path.

7. An electric wave amplifier comprising a path for degeneratively feeding back waves from a posterior point to an anterior point in said amplifier, and oscillation generating means comprising a path for regeneratively feeding back waves from a posterior point in said amplifier to said anterior point, said two paths comprising circuit means common to the two paths for completing them to said anterior point.

8. An electric wave amplifier having input and output means for the waves to be amplified, a feedback path embracing said amplifier adapted for gain-reducing feedback over a range of frequencies including the waves to be amplified, and a path adapted for positive feedback at a frequency within said range comprising circuit means coupling an anterior point thereof with said first-mentioned feedback path in phase-opposing relation with respect to said last-mentioned frequency.

JAMES O. EDSON.