Jan. 5, 1937. R. S. CARUTHERS 2,066,333

WAVE AMPLIFICATION AND GENERATION

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FIG. 1

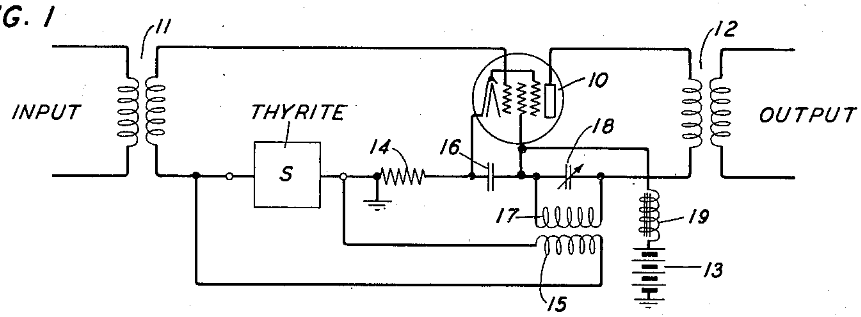


FIG. 1A

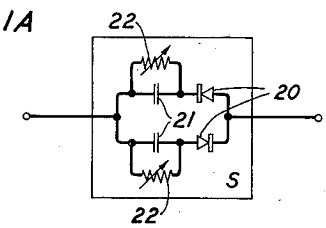


FIG. 1B

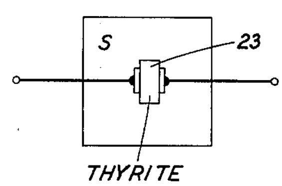


FIG. 2

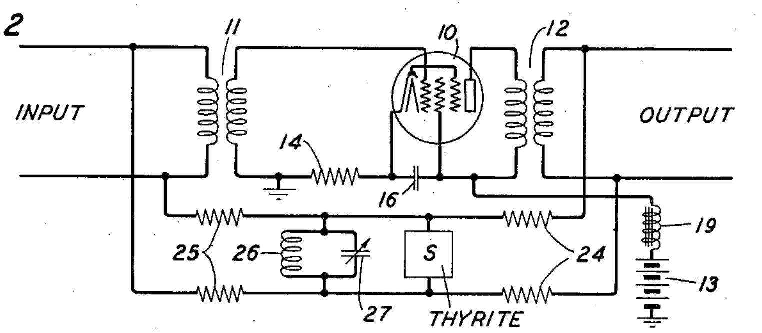


FIG. 3

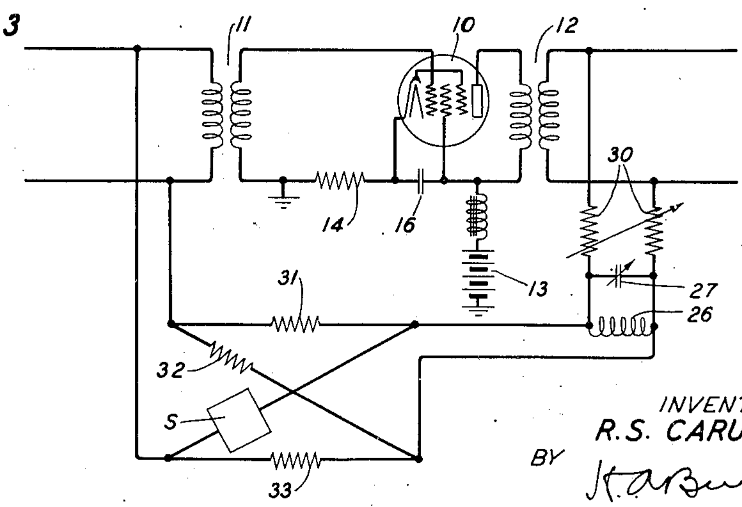


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FIG. 4

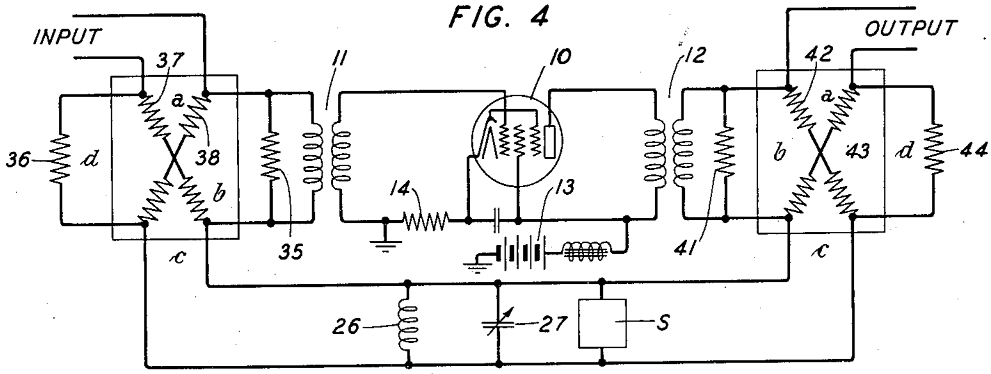


FIG. 5

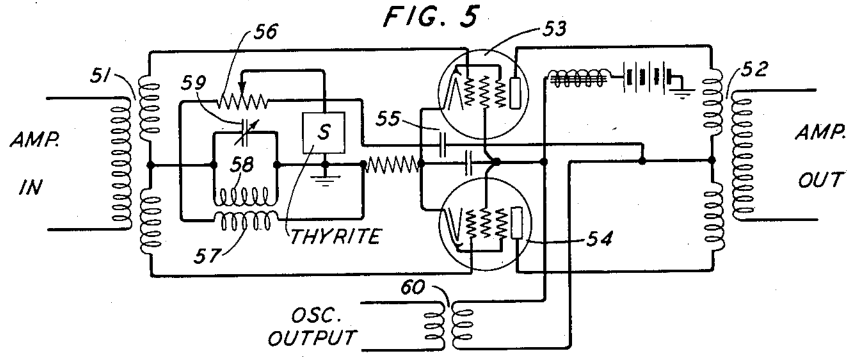


FIG. 6

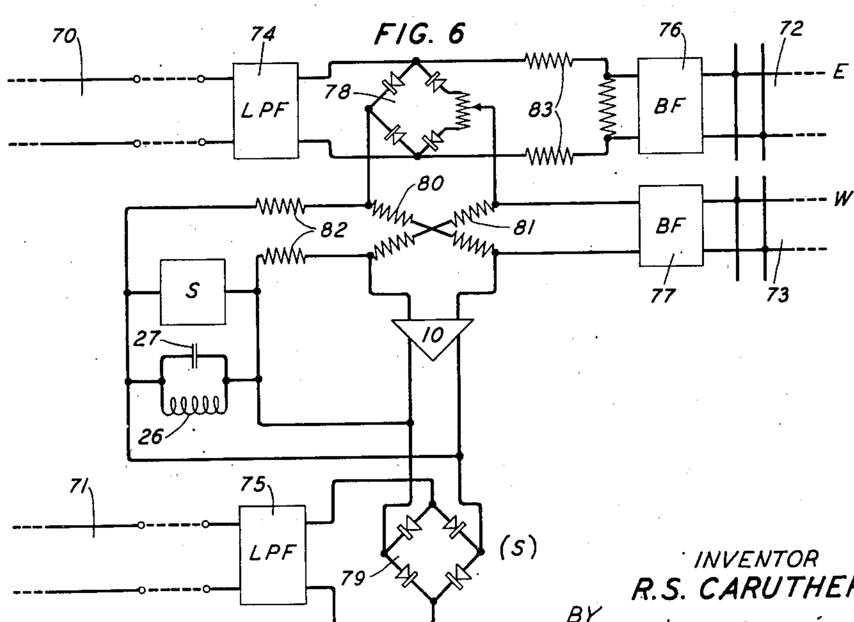


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FIG. 7

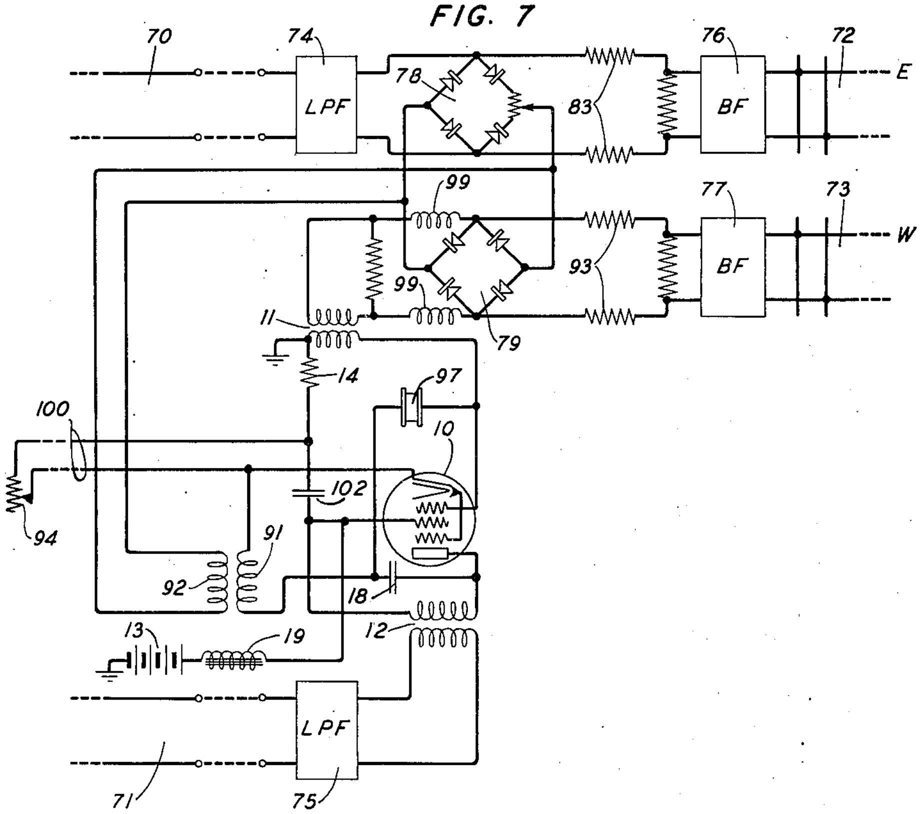
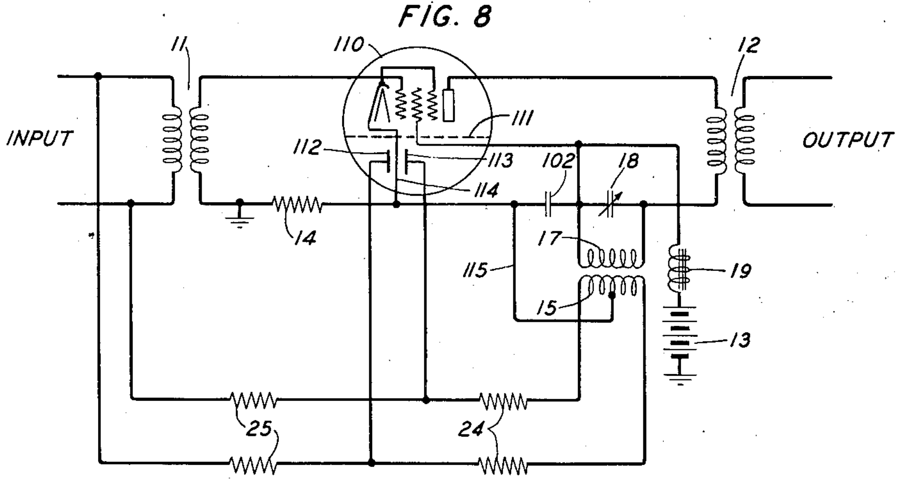



FIG. 8

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# UNITED STATES PATENT OFFICE

2,066,333

## WAVE AMPLIFICATION AND GENERATION

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Application December 14, 1934, Serial No. 757,422

8 Claims. (Cl. 179—171)

The present invention relates to the transmission of waves in two circuits through the same circuit element such as an amplifier without mutual interference. Specifically, the invention relates to an amplifier which simultaneously amplifies waves in a given circuit and generates oscillations of some desired frequency independently of its amplifying action on said waves.

An object of the invention is the simultaneous amplification of waves and the production of oscillations by the same amplifier element.

If attempt be made to use an amplifier that has an overload characteristic, such as is exhibited by space discharge tubes, for amplifying waves and at the same time generating oscillations, it is found that the circuit has a tendency to devote itself entirely to producing oscillations rather than performing both of the intended functions. It is a characteristic of an oscillating system to reach a steady state condition in which the loss in the system is just balanced by the gain. Initially the oscillations start and build up in amplitude until this steady state condition is reached. Usually the limit is fixed by the overload characteristic of the tube or other amplifying element. As the amplitude of the oscillations reaches the overload point the tube losses increase at a steeper rate, or looked at from the standpoint of gain, the gain falls off, with the result that further increase in amplitude is checked and the circuit settles down to an oscillating condition at an amplitude, limited by this overload characteristic. In the usual oscillation generator circuit there is nothing to prevent the oscillations from increasing up to the limit set by the overload point of the tube. If, then, other waves are impressed on the same circuit they cannot be amplified by the tube since there is no margin of load carrying capacity left for the tube over and above that used for oscillation production.

In accordance with the present invention, a circuit is provided with an overload or limiting means which serves to limit the amplitude of the oscillations being generated at a value well below the overload or load-limiting point of the amplifier element, thus leaving a load-carrying margin which can be used for amplifying other waves.

Such a limiting means may take any one of a variety of forms and may be of simple construction. A piece of substance known to the trade as "Thyrite" or a copper oxide rectifier or, in general, any means which exhibits an overload or non-linear relation between current and voltage may be used.

The nature of the invention and its various features and objects will appear more fully in the detailed description to follow, together with the drawings forming a part of this specification.

In the drawings:

Figs. 1, 2, 3, 4, 5 and 8 are schematic circuit diagrams of various forms of circuit for both amplifying waves and generating oscillations in accordance with the invention;

Figs. 1A and 1B show detail views of different types of non-linear resistances; and

Figs. 6 and 7 show the application of the wave amplifying and generating circuit to carrier systems according to the invention.

Referring first to Fig. 1 the pentode vacuum tube 10 is arranged as a combined amplifier and oscillator. For its amplifying function it has an input transformer 11 and an output transformer 12 for connecting respectively to any suitable input circuit and output circuit. The waves that are being amplified may be speech waves or waves of any other suitable type or frequency range and it is assumed that the transformers 11 and 12 and their associated connecting circuits are of suitable design to accommodate the type and frequency of the waves being amplified. Space current for the tube is supplied from a plate battery 13 which also supplies positive potential for the screen. Negative grid bias potential is obtained as the drop across resistance 14, the grid end of which is connected to the minus pole of the plate battery 13, this connection being indicated in the drawings by grounds.

The grid circuit for the wave being amplified is traced from the grid through the secondary winding of input transformer 11, transformer winding 15, bias resistor 14 to the cathode. The output circuit for the speech or other waves being amplified may be traced from the anode through the primary winding of output transformer 12, winding 17, condenser 16 (which may be as large as is required to accommodate the waves being amplified), to the cathode. The path for the space current may be traced from ground through battery 13, choke coil 19, winding 17, primary of output transformer 12 to the anode, thence to the cathode, through bias resistance 14 to ground.

The tube 10 generates oscillations by virtue of the feed-back from the plate tuned circuit comprising the condenser 18 and inductance 17 and the winding 15 which is in the grid circuit. Condenser 18 may be variable as shown to control the frequency of the waves being generated. The block indicated "S" in the drawings is in shunt to the winding 15 and therefore effectively in shunt to the tuned circuit 17, 18. This element "S" of the circuit will be described more fully in connection with Figs. 1A and 1B. It may comprise any suitable element having a non-linear current voltage characteristic or an overload characteristic such as to place an upper limit on the amplitude of the oscillations corresponding to a point below the overload point of the tube 10.

In considering the operation of the circuit of Fig. 1, as an oscillation generator, the oscillations may be thought of as starting from a very low value and building up towards the steady state condition. For low amplitude oscillations the element S has very high impedance so that substantially the full voltage of the oscillations generated in the coil 15 is applied to the grid. After the oscillations have reached a certain value, however, the effective resistance of the element S falls to a low value and any tendency towards a further increase in the oscillations is counteracted by the tendency of the element S to fall to a still lower resistance, thus limiting the oscillation voltage that is applied to the grid. The oscillations therefore are limited in their maximum amplitude by the operation of the element S. This element is proportioned to limit the oscillations to a value less than they would have if the element S were absent and if the tube 10 performed the limiting function as in the case of the ordinary oscillation generator. The limit set to these oscillations may be sufficiently low to permit the tube 10 to operate effectively as an amplifier for the waves impressed on the tube through the input transformer 11.

The details of one type of circuit which may comprise the element S are shown in Fig. 1A. In this case two copper oxide rectifiers poled in respectively opposite directions are connected in parallel between the terminals of the element S. In some instances it may be found sufficient to employ only these two rectifiers without any biasing means or they may be biased in any suitable manner as by a battery (not shown) or by the means shown in this figure, comprising a resistance 22 in series with each rectifier shunted by a small condenser 21. When waves are developed across the terminals of the element S one or the other of the rectifiers 20 conducts current depending upon the polarity of the applied wave at the particular instant, and the current so transmitted through the rectifier in question develops a voltage across resistance 22 which is stored in shunt capacity 21. This voltage serves to polarize the corresponding rectifier element. The polarizing or bias potential applied to the rectifier aids in determining the overload point of the rectifier. It also increases the sharpness of the overload characteristic of the rectifiers as the oscillation builds up. This is very important from the standpoint of stability.

A second type of element S is shown in Fig. 1B and comprises an element 23 of a material known in the trade as Thyrite, comprising a mass of silicon carbide crystals and a suitable binder as specifically described and claimed in U. S. patent to McEachron 1,822,742 granted September 8, 1931. This material has a non-linear resistance characteristic.

The invention is not limited to the use of the two types of non-linear resistances shown in Figs. 1A and 1B since any suitable type of non-linear resistance may be used, including other than solid materials, for example a space discharge device.

The circuit of Fig. 1 represents one type of series feed-back in which the feed-back circuit is in series with both the output and the input circuits of the tube 10. This type of circuit has been referred to in the art as "series-series" feed-back. Other types of feed-back circuits are possible in which the feed-back connection on the output side may be either series or parallel and on the input side may be either series or parallel, making possible the types of feed-back (in addition to the series-series type) which may be identified as the shunt-series, the series-shunt and the shunt-shunt types. It will be noted that in the circuit of Fig. 1 the oscillations that are generated by the tube 10 are applied to the output circuit through the transformer 12 but they are substantially kept out of the input circuit because of the series relationship between the feed-back connection on the input side and the secondary of the input coil 11.

Fig. 2 represents a type of shunt-shunt feed-back, that is, one in which the feed-back circuit is in shunt to the amplifier circuit on both its output and its input sides. In this figure various elements are identified with corresponding elements of Fig. 1 by the use of similar reference characters. The essential difference is that the feed-back circuit in this figure is connected in parallel to the output and to the input circuit, specifically outside of the coils 11 and 12, that is, on the side remote from the tube 10. This feed-back circuit could, however, be connected inside these coils with generally similar results. The feed-back circuit includes resistance elements 24 and 25 offering a high impedance to the transmission of current directly between the input and output circuits. It also includes the parallel combination of inductance 26 and condenser 27 which together form the frequency determining element of the oscillating system, and the limiting element S, which is also in shunt of the feed-back path.

By virtue of this connection, the only waves which are effectively transferred from the output to the input circuit are waves having a frequency corresponding to the anti-resonant frequency of the circuit 26, 27 and having an amplitude below a certain maximum which is determined by the point at which the shunt element S begins to introduce sufficiently low conductivity. The circuit, therefore, generates oscillations of amplitude below the overload point of the element S which, by design, may be made sufficiently lower than the overload point of the tube 10 to permit this tube also to amplify other waves from the input into the output circuit. If it is desired that the oscillations be transmitted in both directions from the tube 10, that is, both into the input and into the output circuit, a shunt type of connection, one example of which is shown in Fig. 2, may be used.

Fig. 3 shows a modified type of shunt feed-back circuit including a bridge comprising three resistance arms 31, 32, 33 with the element S as the fourth arm of the bridge. The frequency determining circuit is the resonant parallel combination, inductance 26 and capacity 27, this being effectively isolated from the output by a suitable resistance pad 30 which prevents the resonant circuit from appearing as effectively shunted across the output where it might influence the transmission of waves in an undesired manner. By properly proportioning the resistances 31, 32 and 33 and the element S, the bridge may be unbalanced for low amplitudes of the current being generated, thus effectively feeding this current back to the input. As the amplitude of current in the feed-back circuit increases, however, the bridge approaches a condition of balance by virtue of the change in resistance of the element S so that further increases in amplitude tend to feed back less and less to the input. The limiting point is reached as the result of the two-fold action of the bridge and of the non-linear resistance of the element S. By making some of the resistances 31, 32, 33 variable or by choosing proper values for these resistances the point of balance of the bridge may be controlled and thus the limit of amplitude of currents generated may be controlled. As in the other figures the tube 10 may serve for the amplification of waves of any desired type independently of the currents generated.

Fig. 4 shows a circuit generally similar to that of Fig. 2 but employing bridge circuits between the input and the feed-back and between the output and the feed-back circuits, in order to separate interaction effects between oscillating and amplifier circuits. The input bridge is made up of four arms comprising resistances 37 and 38, resistance 35 shunting input coil 11 and a fourth or balancing resistance 36. In the case of the output bridge, resistance 41 shunting the output of coil 12 forms one arm of the bridge, resistance 44 forms the opposite arm while the other two arms are comprised of resistances 42 and 43. For a perfect balance between the sides *a* and *c* of the input bridge the circuit could be made to generate oscillations without substantially any of these oscillations getting into the input circuit. A balance between sides *a* and *c* of the output bridge prevents currents in the output circuit beyond the bridge from getting back into the feed-back circuit. Currents flow into the output circuit, however, from *b* to *a*. By a choice of ratio arms the loss between the sides *a* and *b* of each bridge may be made low while the loss between sides *b* and *c* may be made high. Thus the amount of current flowing in the feed-back path may be made small in comparison with that supplied to the output circuit. Speech waves or other signals transmitted through the circuit are effectively transmitted to the input of the amplifier 10 and from the output side of this amplifier into the output circuit.

In each of the circuits that have been described, if the ratio of reactance to resistance of the tuned circuit 26, 27 is made high this circuit becomes a low impedance shunt to currents of all frequencies except the resonant frequency. Currents other than the resonant frequency are, therefore, effectively prevented from being fed back.

In Fig. 5 the tubes 53 and 54, each of which may be similar to tube 10 of the other figures or of any other suitable type, are connected in push-pull relation as regards the input circuit connected to input coil 51 and the output circuit connected to output coil 52. These tubes amplify waves of any suitable type impressed on the input circuit, acting as a push-pull amplifier for this purpose. Tubes 53 and 54 generate oscillations in a parallel circuit by virtue of a feed-back circuit connecting the common branch of the output circuit with the common branch of the input circuit. This feed-back circuit is traced through large condenser 55, resistance 56 and inductive winding 57, the latter of which is coupled to the inductance 58 of the tuned circuit comprising inductance 58 and condenser 59. The limiting element S is connected between the common branch of the input circuit and an adjustable point along the resistance 56. The oscillations may be taken off through output winding 60 and applied to any suitable load circuit. The load limiting element S is virtually in shunt to the tuned circuit 58, 59 since it is connected across the primary winding 57 in somewhat the same manner as in Fig. 1. The amount of oscillating current voltage impressed across the terminals of the device S is controlled by the position of the slider on the resistance 56 so that for a given type of element S the amplitude of the oscillations generated before the limiting action of the element S sets in may be controlled by adjustment of the slider on the resistance 56.

Fig. 6 indicates a terminal of a carrier telephone system comprising an eastward multiplex line 72 and a westward multiplex line 73. One branch for each line is shown in Fig. 6 and may be similar to other branches. For the transmitting line 72 band filter 76 leads to a modulating circuit connected on the other side to low frequency line 70 which may lead to an exchange where it is extended as a voice frequency line on either a four-wire or two-wire basis.

The westward or receiving line is shown with band filter 77 leading through resistance bridge network 81 and receiving amplifier 10 to demodulator 79, the output of which is connected through low-pass filter 75 to voice line 71 which may lead to the same point as voice line 70. These two voice lines 70 and 71 may be considered as eventually connected to a subscriber's line for two-way talking.

The modulator 78 and the demodulator 79 are each shown as of the bridge type employing non-linear resistances which may be copper oxide rectifiers, for example. The speech is applied across one diagonal of the bridge while the carrier used for modulating or demodulating purposes and, in the case of demodulator 79, the sideband, are applied across the opposite diagonal.

The receiving amplifier 10 is provided with a feed-back circuit comprising frequency-determining combination 26, 27 and element S in a circuit similar to that of Fig. 4 except that the bridge of Fig. 4 is omitted in this figure on the output side of the amplifier. The amplifier 10, therefore, serves as an oscillation generator producing waves of carrier frequency which are applied to the modulator 78 and the demodulator 79. The bridge comprising ratio arms 80 and 81 and as its other arms modulator 78 and input of amplifier 10 is balanced so that the oscillations generated by the tube 10 are not applied to band filter 77. The bridge is preferably adjusted so that the loss from the feed-back path into modulator 78 is low whereas the loss into the input of amplifier 10 is high. It is assumed that the same frequency carrier wave is used for a given channel on each line 72 or 73.

The operation of the circuit of Fig. 6 is as follows: Speech waves coming from the speech line to which line 70 is connected pass through low-pass filter 74 and modulate in the modulator 78 the carrier wave supplied from the amplifier-oscillator circuit 10, 26, 27. Modulator 78 is balanced so that the unmodulated carrier component is not transmitted. To aid in securing this balance a potentiometer is included between two of the copper oxide elements as shown, equipped with a slider to which one of the carrier input terminals is connected. One sideband of the resulting modulated wave is transmitted from resistance network 83 through band-pass filter 76 into the outgoing line 72. Resistance network 83 is a pad preventing transmission irregularities due to interaction of copper oxide and band filter reactances. In similar fashion waves from other lines similar to line 70 in other channels are used to modulate carrier waves of other frequencies and the resulting sideband frequencies are transmitted through other band filters to the same line 72.

By a terminal circuit which may be identically similar to that disclosed above but located at the other end of line 73, a number of sideband modulated waves are produced and transmitted over the line 73 to the station shown on the drawings. One of these sidebands passes through band filter 77 and is impressed on the bridge circuit previously described of which two of the arms are the resistances 80 and 81, and then on the input of receiving amplifier 10 where they are amplified and impressed on one diagonal of the modulator 79. Some of the carrier wave generated in the circuit comprising amplifier 10 is impressed together with the sideband components on the demodulator 79. The demodulated voice frequency components are then transmitted through the low-pass filter 75 and impressed upon the voice frequency line 71. The bridge including resistances 80 and 81 may be so proportioned that the loss from the output of band filter 77 to the input of amplifier 10 is low whereas the loss from the band filter 77 into the modulator 78 is high.

A feature of considerable interest and importance in connection with a circuit of the type shown in Fig 6, where the combination amplifier-oscillator 10 feeds into a non-linear resistance circuit such as 79, is that the element S may be omitted because of the non-linear resistance characteristic of circuit 79; and the amplifier 10 may be made to perform the two-fold function of generating oscillations and amplifying waves. For this purpose the non-linear circuit 79 furnishes the overload characteristic for determining the maximum amplitude of the oscillations generated in the circuit in the same manner as is described hereinbefore in connection with the element S. This represents a simplification.

Fig. 7 discloses a circuit generally similar to that of Fig. 6 but capable of greater accuracy in the frequency of the generated carrier wave. The type of oscillator circuit disclosed is essentially that of Fig. 2, a shunt type, but it includes a crystal 97 for accurately determining the frequency of the waves generated. It also makes use of the fact that the impedances of coils 11 and 12 are fairly pure capacity reactances at carrier frequencies on the sides facing the tube. Condenser 18 and coil 91 are arranged so that small shunting action is inserted across the high winding of coil 12 at voice frequencies. Also the junction between condenser 18 and coil 91 is effectively connected to the plate at carrier frequency and to cathode at voice frequency. This allows feed-back at carrier but none at voice frequency. Crystal 97 lies in the feed-back connection from the junction of coil 91 and condenser 18 to the grid. This makes for greater constancy of frequency of oscillations generated, as for example, with temperature changes. The output of tube 10 for the generated oscillations is from winding 91 to inductively coupled coil 92 which is connected to modulator 78 and demodulator 79.

The space current circuit for the tube 10 may be traced from ground through battery 13, choke coil 19, primary output coil 12 to the anode of tube 10, thence to the cathode, through one side of circuit 100, resistance 94, opposite side of circuit 100, resistance 14, for grid bias, back to ground. It is thus seen that both resistor 14 and variable resistance 94 are included between the cathode and ground or minus "B". The path that is traversed by speech waves is from anode through primary winding of output coil 12, condenser 102 and resistance 94 to the cathode, so that resistance 94 represents a coupling from plate to grid circuit for speech waves, this coupling being of such sign as to reduce the degree of amplification for the speech waves. The resistance 94 being variable offers a control for the gain of the amplifier tube 10 since variations in this resistance control the amount of voltage of voice frequency (as well as direct current) that is fed back reversely on the grid. The leads 100 may be extended to a convenient point for mounting the control 94 along with similar controls for other receiving channels.

It will be noted that the copper oxide rectifiers in modulator 78 are so poled with respect to those in demodulator 79 that carrier waves applied to both modulator and demodulator from the coil 92 flow alternately through 78 and 79 in opposite half waves of the carrier. This form of connection of the modulator and demodulator to the carrier supply circuit affords an impedance which is favorable to the suppression of second order harmonics from the carrier supply circuit. In some types of modulators such as those employing copper oxide rectifiers the second harmonic frequently has the largest amplitude of any harmonic. For efficiency reasons it is advantageous to have this relatively strong harmonic current dissipated by circulating through the modulator and demodulator circuit as is done in the type of circuit of Fig. 7.

The operation of Fig. 7 is generally similar to that described in Fig. 6. Speech waves in line 70 are transmitted through the modulating apparatus and eventually into eastward carrier line 72 in the same manner as described in Fig. 6. Modulated carrier waves received over line 73 from the opposite station pass through band filter 77 and are demodulated at 79. The inductances 99 offer high impedance to the sideband current in shunt of the modulator 79 but permit the passage of speech waves with low loss. The resulting speech waves are impressed on the amplifier 10 through input coil 11 and from the output of the amplifier 10 they pass through output coil 12, low-pass filter 75 into line 71. By varying resistance 94 the gain of the amplifier 10 for the speech waves may be varied. The tube 10 continually produces oscillations of the carrier frequency as determined by the crystal 97 and the carrier frequency waves are supplied to both the modulator 78 and demodulator 79. The non-linear impedance which limits the maximum amplitude of the generated carrier oscillations is that of modulator 78 or demodulator 79 which are effectively connected across 91, by virtue of the coupling of coil 92 to this circuit. The maximum amplitude of the oscillations is limited to a point sufficiently below the overload point of amplifier 10 to permit the efficient amplification of the detected speech waves.

In a carrier system for several channels in each direction employing a terminal circuit of the type shown in either Fig. 6 or Fig. 7 each transmitting channel at a station is paired with a corresponding receiving channel, the same carrier frequency wave is used for both channels and is produced in a common oscillating circuit as disclosed. Oscillating circuits of identically the same carrier frequency are, of course, employed at the opposite terminal for each pair of channels.

Fig. 8 shows a type of circuit in which the non-linear resistance used to limit the amplitude of the oscillations being generated comprises space discharge paths included preferably in the same tube with the amplifying elements. The type of tube 110 disclosed for this purpose is known as a duplex diode pentode tube, and is preferably provided with an internal shield 111 effectively separating the portion of the bulb including the diode plates 112 and 113 from the portion including the usual pentode elements such as control grid, space charge grid, screen grid and anode. The same cathode 114 may serve for both sets of electrodes and is shown extending through the shield 112.

The operation of the circuit is generally similar to that of the earlier figures. Input coil 11 and output coil 12 enable the tube to be connected between input and output circuits for amplification of waves as in the other figures. Condenser 102 is large enough to pass readily the wave being amplified. Tuned circuit 18, 17 determines the frequency of the oscillations generated, the feed-back path comprising secondary winding 15 and resistances 24 and 25 somewhat as in Fig. 2. For low amplitude waves in the feed-back circuit the space paths between anode 112 and cathode 114 and between anode 113 and cathode 114 offer high shunt impedance and the oscillations build up to a point where these space paths introduce a limiting effect. In other words one or the other such space path is a non-linear resistance in shunt to the half of the coil 15 which is at any instant driving the anode 112 or 113 positive with respect to cathode 114, the shunt path being completed through the lead 115 and one of the resistances 24. Such non-linear shunt resistance limits the value of the oscillation current that is allowed to build up in the feed-back path. By proper design the space paths 112—114 and 113—114 can be made to reach a low resistance point well below the overload point of the tube 110 for the waves which are being amplified by it. The shield 111 prevents undesired influence of the discharge spaces 112—114 and 113—114 upon the elements of the tube used for amplification.

The circuit of Fig. 8 may be used alternatively to the circuits that are shown provided with an overload device S, in the carrier systems of Figs. 6 and 7.

The circuits that have been shown and described are to be taken as illustrative rather than as limiting, since the invention is capable of embodiment in many forms including forms other than those specifically shown. The scope of the invention is defined in the claims.

What is claimed is:

1. In combination a space discharge tube having an input and an output circuit, a feedback coupling for causing said tube to act as a generator of sustained oscillations, means to utilize the generated oscillations, a resistor of non-linear characteristic connected to said tube to limit the amplitude of the generated oscillations to a value below that corresponding to the limit of the load-carrying capacity of the tube, whereby a portion of the load-carrying capacity is left unused in the production of the oscillations, means to impress waves, independently of the oscillations being generated, upon the input circuit to be amplified by said tube, and means in the output circuit to utilize the amplified waves.

2. In combination, an amplifying element, input and output circuits therefor, for enabling said element to amplify waves impressed on said input circuit, a feed-back circuit to enable said element to generate oscillations, and amplitude limiting means in a path traversed by said oscillations but outside the path traversed by said waves.

3. In combination, a circuit traversed by waves, an amplifier effectively in said circuit for amplifying said waves, a feed-back path for said amplifier for causing the amplifier to generate oscillations and a current limiting means operative to limit the amplitude of the oscillations, said means being effectively outside of the path traversed by said waves.

4. In combination, an amplifier having an input circuit and an ouput circuit, a source of waves to be amplified connected to said input circuit and a utilization circuit for the amplified waves connected to said output circuit, a feed-back path forming with said amplifier and its input and output circuits a system for generating oscillations independently of its function of amplifying waves from said source, means to utilize the generated oscillations, and a non-linear resistance effectively in the oscillation generating system for limiting the amplitude of the generated oscillations.

5. In combination, a main circuit transmitting waves, an amplifier having an input circuit and an output circuit effectively connected to said main circuit to amplify the waves transmitted by it, a feed-back circuit from the output to the input of said amplifier for causing the amplifier to generate oscillations, means to utilize the generated oscillations, means limiting the amplitude of the generated oscillations to a value below that corresponding to the limit of the load-carrying capacity of said amplifier, said feed-back path being connected to the input circuit of said amplifier in parallel relation with the main circuit.

6. In combination, a main circuit transmitting waves, an amplifier having an input circuit and an output circuit effectively connected to said main circuit to amplify the waves transmitted by it, a feed-back circuit from the output to the input of said amplifier for causing the amplifier to generate oscillations, means limiting the amplitude of the generated oscillations to a value below that corresponding to the limit of the load-carrying capacity of said amplifier, said feed-back path being connected to the input circuit of said amplifier in series relation to the main circuit.

7. In combination, a main circuit transmitting waves, an amplifier having an input circuit and an output circuit effectively connected to said main circuit to amplify the waves transmitted by it, a feed-back circuit from the output to the input of said amplifier for causing the amplifier to generate oscillations, means limiting the amplitude of the generated oscillations to a value below that corresponding to the limit of the load-carrying capacity of said amplifier, said feed-back path being connected to the output circuit of said amplifier in parallel relation to said main circuit.

8. In combination, a main circuit transmitting waves, an amplifier having an input circuit and an output circuit effectively connected to said main circuit to amplify the waves transmitted by it, a feed-back circuit from the output to the input of said amplifier for causing the amplifier to generate oscillations, means to utilize the generated oscillations, means limiting the amplitude of the generated oscillations to a value below that corresponding to the limit of the load-carrying capacity of said amplifier, said feed-back path being connected to the output circuit of said amplifier in series relation to said main circuit.

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